Metadata and Data Standards. Sharing Data in Hydrology: Best Practices

Ilya Zaslavsky
San Diego Supercomputer Center

LMI Workshop, Hanoi, August 18-22

/ With several slides from last week's HDWG workshop,
presented by HDWG members Irina Dornblut, Paul Sheahan, and others/

Outline

- Why use standards?
- Open Geospatial Consortium, and spatial data standards
- Standards for water data, and the OGC/WMO Hydrology Domain Working Group
  - history, activities, WMO connection, workshop last week
  - Suite of water data standards
- WaterML 2.0 in detail (optional)
- Assessing compliance, and the CINERGI project (optional)

Why sharing data in LMI?

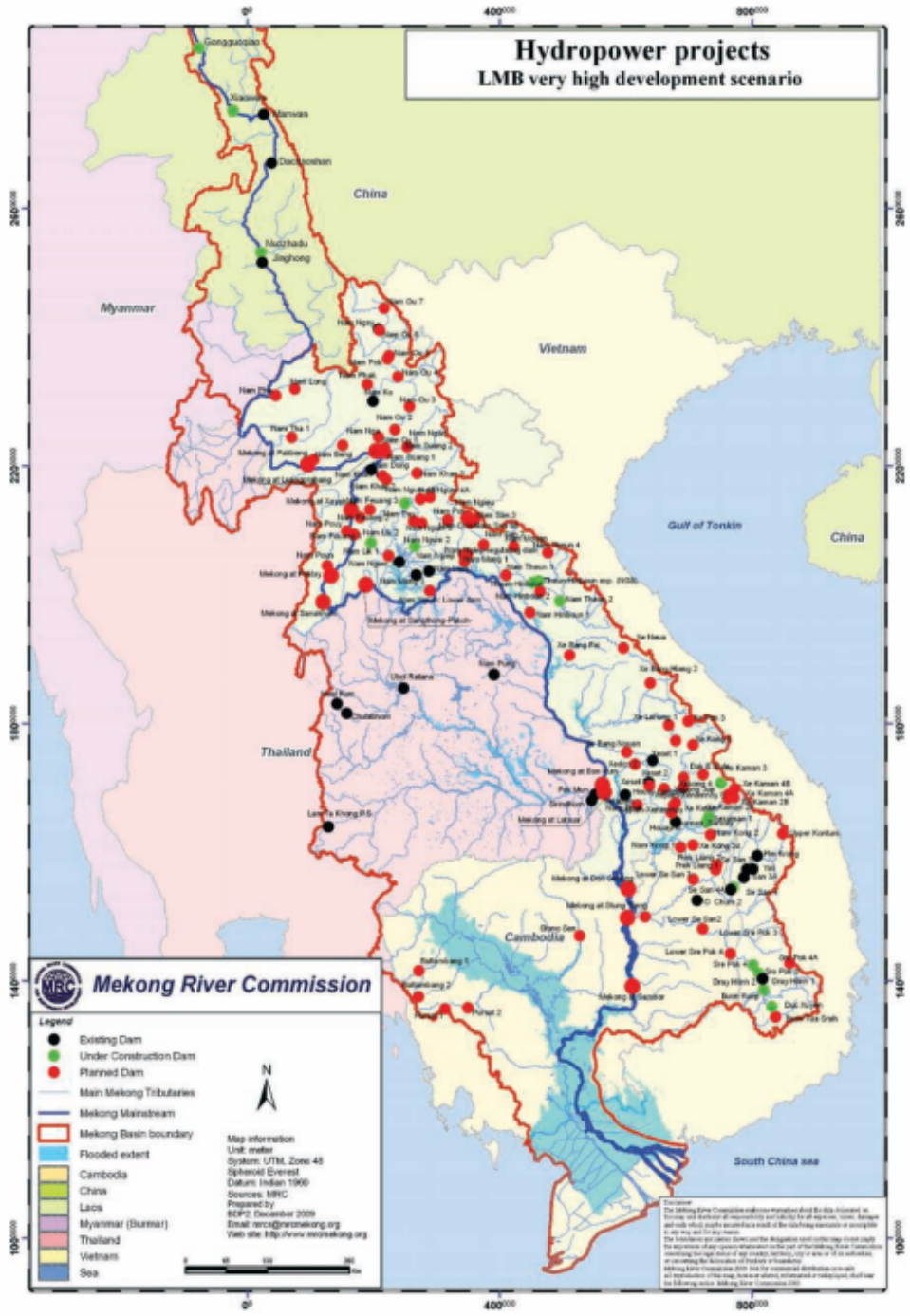
Regional threats

Flow contribution:

- China 16%
- Myanmar 2%
- Thailand 18%
- Lao PDR 35%
- Cambodia 18%
- Vietnam 11%

International river, 2009

- Several countries rely on the Mekong but data sharing is complicated



Existing or planned dams on the Mekong river

Challenges:

Habitat alteration

Pollution

Extreme weather events

Over-exploitation of resources

Diseases and invasive species

Poverty and social instability

. . .

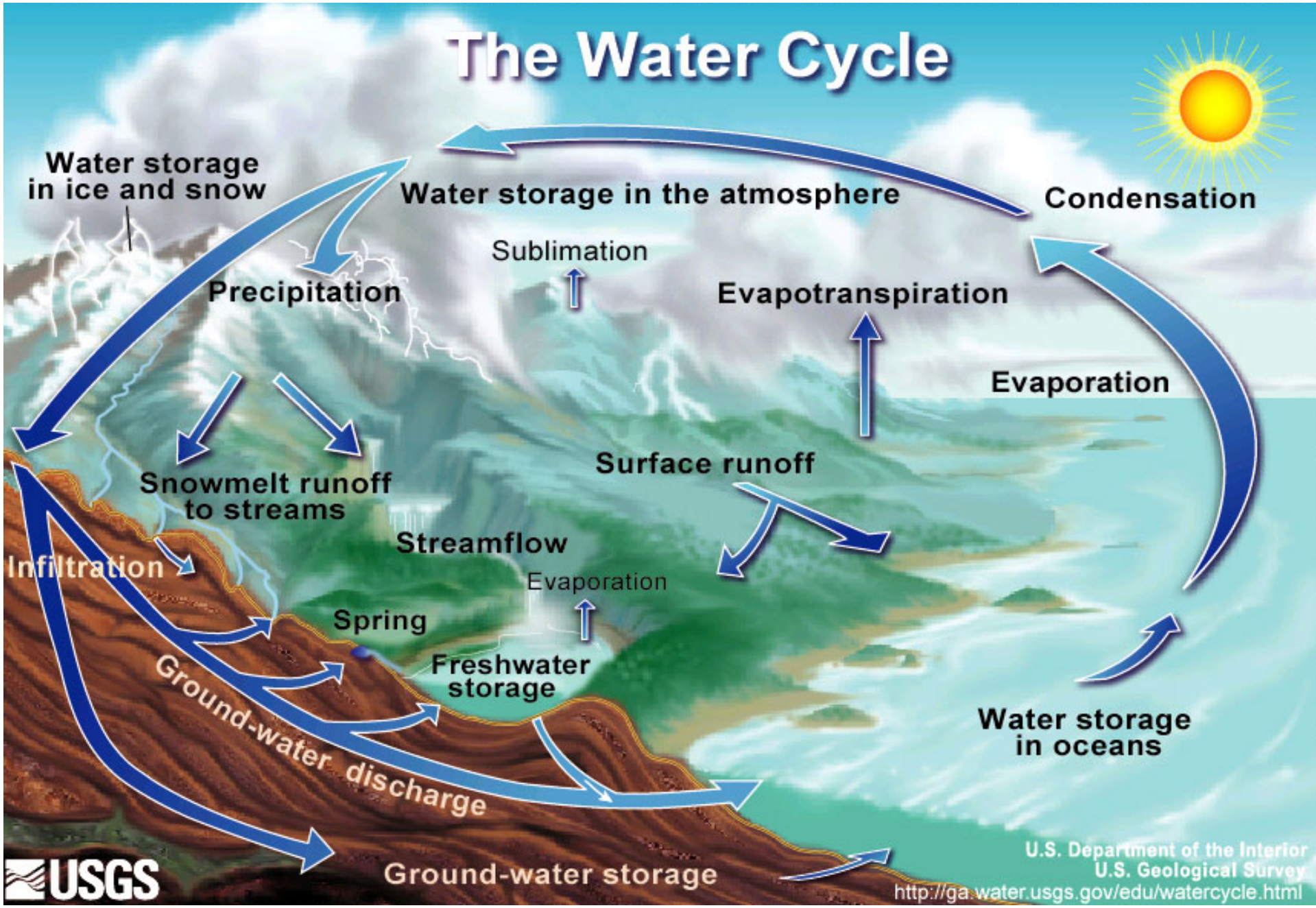
Hydro-power dams on the Mekong river:

- Existing
- Under construction
- Planned

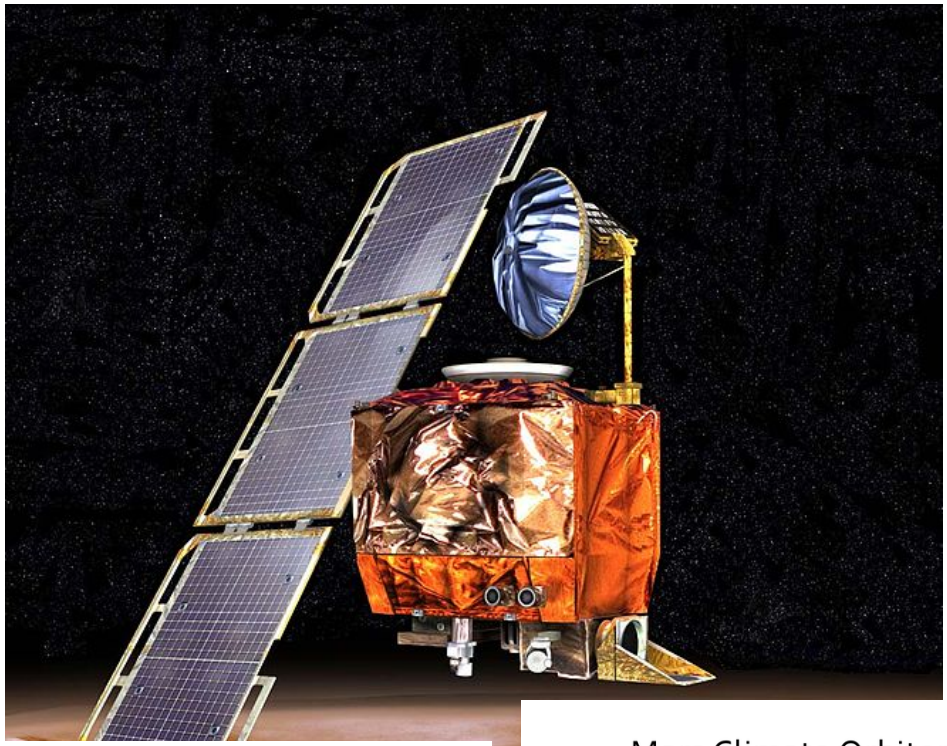
Water - our most valuable asset but …

- In many places we can't assess
  - How much we have
  - Where it is
  - Who owns it
  - What it is fit for
  - How much we will have
  - Where it will be

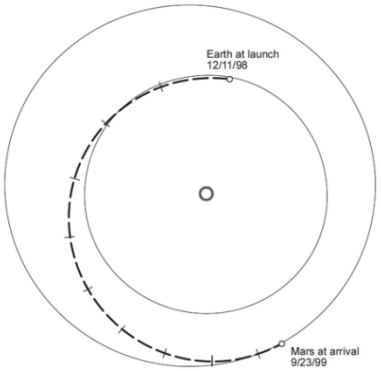
- We certainly can't yet share information in a useful timeframe
  - In particular given the complexity of water cycle


The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Surface runoff
Snowmelt runoff to streams
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
USGS
U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html

Why is it important to coordinate?

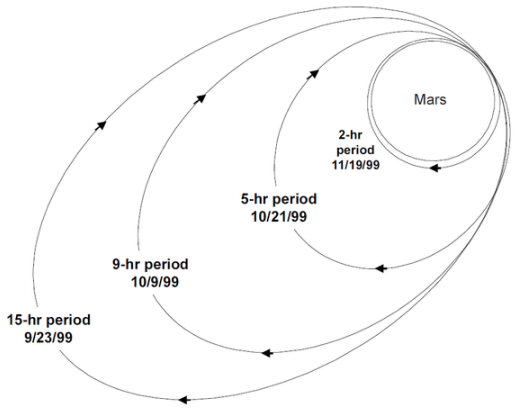


Mars Climate Orbiter



Orbiter's interplanetary trajectory

Mars Climate Orbiter



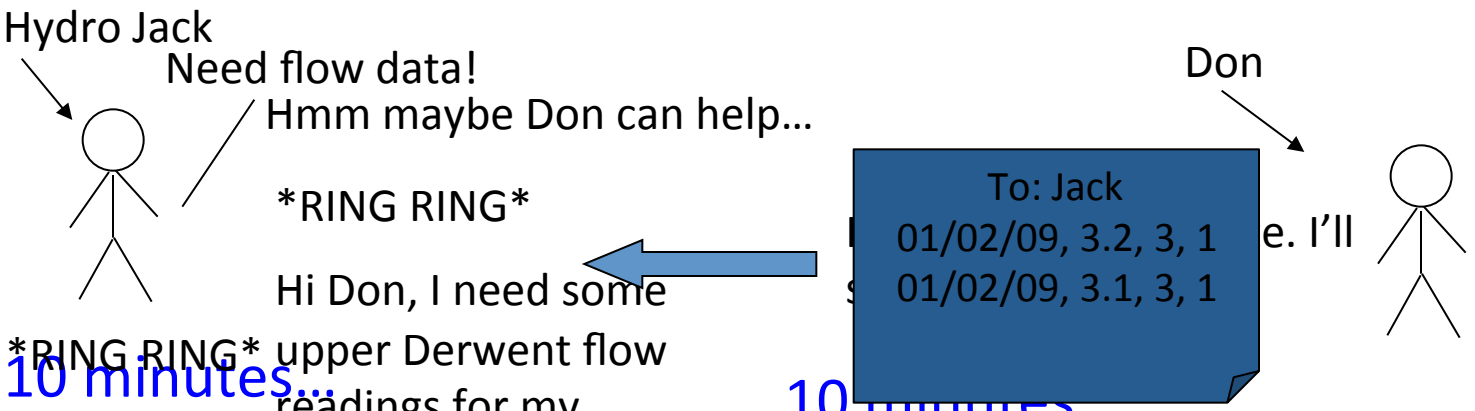
Aerobraking orbits

- The orbiter was taken within 57 km of the surface where it likely disintegrated

Why?

- The flight system software used metric units (Newtons); software on the ground used the Imperial system (pound-force, or lbf)

A common situation in hydrology…



From Peter Taylor (CSIRO)

WaterML2 Adoption

OGC®
KISTERS
Pioneering

...rporate site at www.kisters.de

... & Events Contact Us

UNITED STATES
7777 Greenback Lane,
Suite 209
Citrus Heights, CA 95610-5800

WaterML 2.0 Adopted as an Official OGC Standard

The results of a public voting process have confirmed

The process of standardizing WaterML 2.0 started in 2009/2010 with a "Harmonization Paper", followed by a "Specification Document" in 2011/2012. As an active long-term supporter of open standards KISTERS has provided both its unique global experience in hydrology, as well as specific expertise in time series data management during the development and testing phases of WaterML 2.0.

Now that WaterML 2.0 has been chosen as a standard other regional formats that have been developed, like the Water Data Transfer Format (WDTF) in Australia, the WaterOneFlow and WaterML 1.0 developed by the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) in the U.S., the xHydro standard in Germany, and the EA XML standard in the United Kingdom may soon be replaced. "In my opinion, the standardization of WaterML 2.0 is truly a watershed event that stands to define the future of data sharing in the hydrology community", says Fuest.

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0.3.0	CUAHSI WaterML	07-041r1	DP
	Harmonising Standards for Water Observation Data – Discussion Paper	09-124r2	DP
	WaterML 2.0 – Timeseries – NetCDF Discussion Paper	12-031r2	DP

End of theme 1, start on HDWG

Interoperability: Definitions

- "the ability of two or more systems or components to exchange information and to use the information that has been exchanged"

  IEEE Standard Computer Dictionary. A Compilation of IEEE Standard Computer Glossaries : 610. IEEE, New York (1991)

- "the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires minimal knowledge of the unique characteristics of those units"

  ISO/IEC 2382:2001. Information Technology Vocabulary – Fundamental Terms

Interoperability is about agreements

- **Technical** agreements cover formats, protocols, security systems, so that messages can be exchanged.
- **Semantic**: Content agreements cover the data and metadata, and include semantic agreements on the interpretation of the information.
- **Organizational** agreements cover the ground rules for access, preservation of collections and services, payments, authentication, etc.

Also adopted by IDABC: European Interoperability Framework for pan-European eGovernment Services. European Commission, Luxembourg (2004), now introducing political and legal level (here subsumed in organizational).

Benefits of open standards

- Prevents a single group from controlling a standard
- Facilitates competition
- Stimulates innovation
- Customers benefit from not being locked into a particular supplier
- Lower costs and learning curves for equipment, software development, tools, training, and maintenance

But: learning and applying standards initially adds a layer of complexity and coordination

- an important consideration for researchers working on term-limited projects, especially smaller projects

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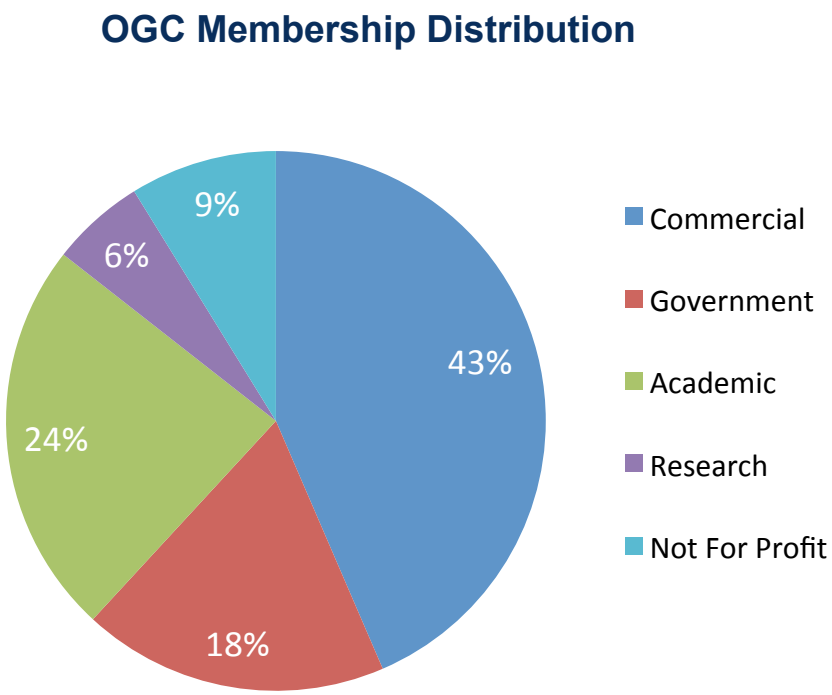
OGC Snapshot

- A Voluntary Consensus Standards Organization, founded in 1994.
- 480 members
- 38 adopted standards
- Hundreds of product implementations
- Broad user community implementation worldwide
- Alliance partnerships with 30+ standards & professional orgs



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Making Location Count...

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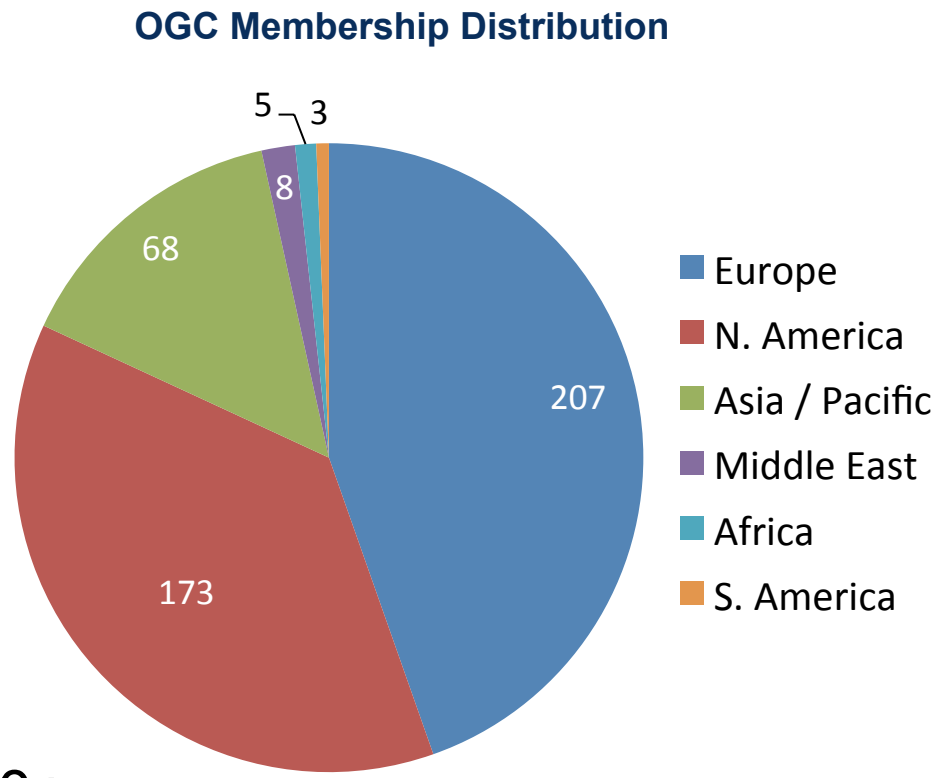

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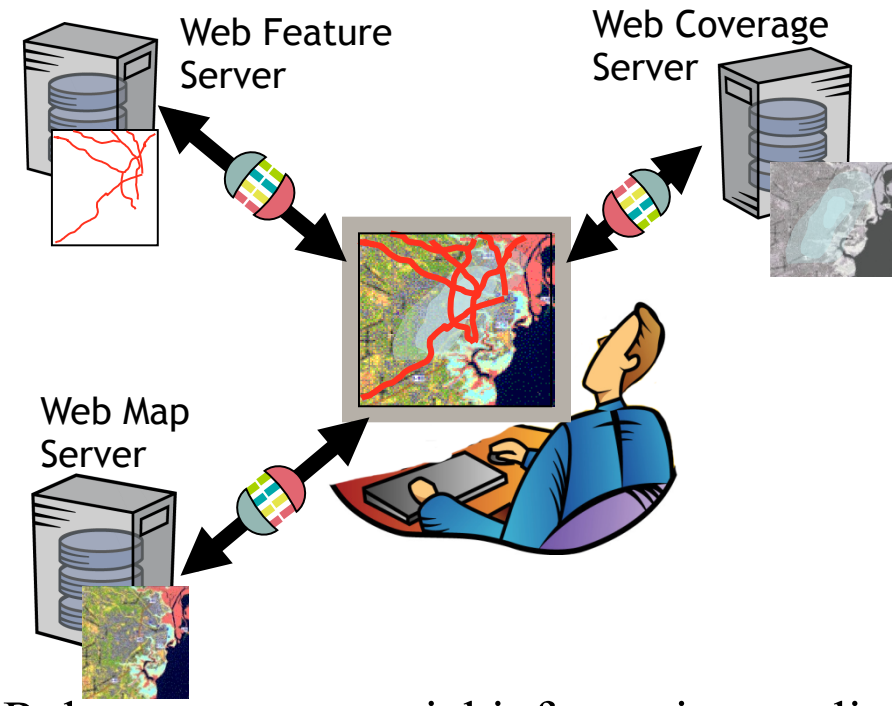
Making Location Count...

OGC Web Services (OWS)

Just as http:// is the dial tone of the World Wide Web, the **geospatial web** is enabled by OGC standards:

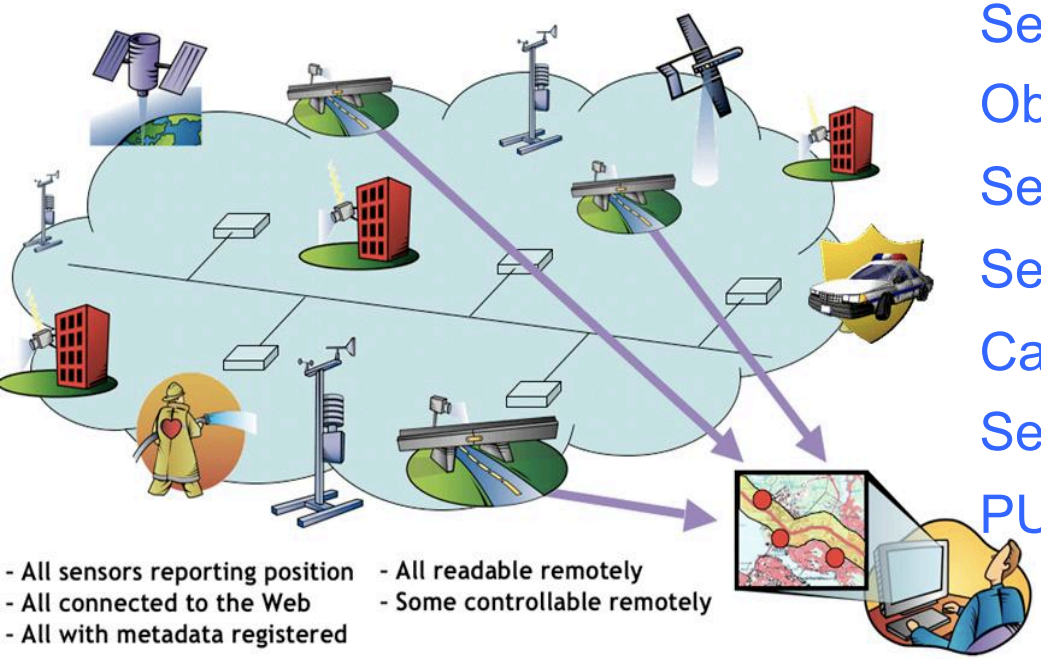


- Web Map Service (WMS)
- Web Map Tile Service (WMTS)
- Web Feature Service (WFS)
- Web Coverage Service (WCS)
- Catalogue (CSW)
- Geography Markup Language (GML)
- KML
- GeoSMS
- Others…

Relevant to geospatial information applications: Critical Infrastructure, Emergency Management, Weather, Climate, Homeland Security, Defense & Intelligence, Oceans Science, others

OGC Sensor Web Enablement Standards

Discovery and tasking of sensor assets, and the access and application of sensor observations for enhanced situational awareness



Sensor Model Language (SensorML)

Observations & Measurements (O&M)

Sensor Planning Service (SPS)

Sensor Observation Service (SOS)

Catalogue Service

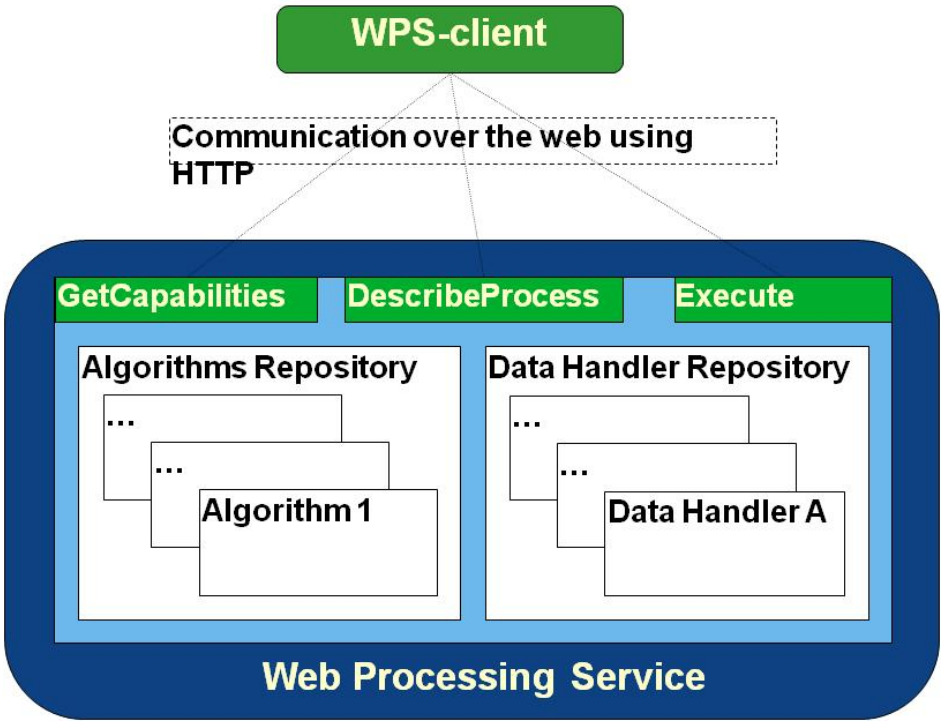
Sensor Alert Service (SAS)

PUCK

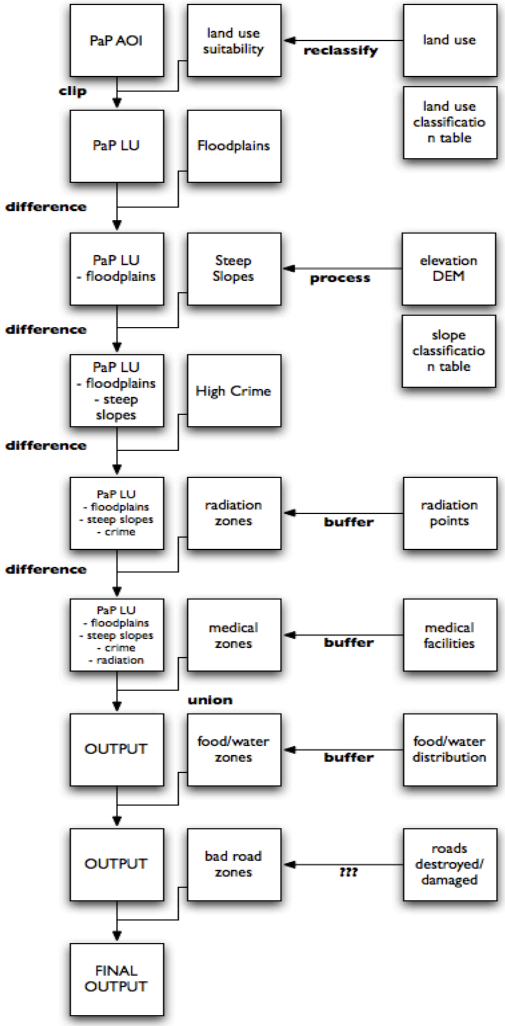
Geospatial Processing, Analysis, Workflow

Web Processing Service – WPS

- OGC Web Service access to algorithms
- Change detection, coordinate transformation, modeling and simulation…



Geoprocessing Workflow



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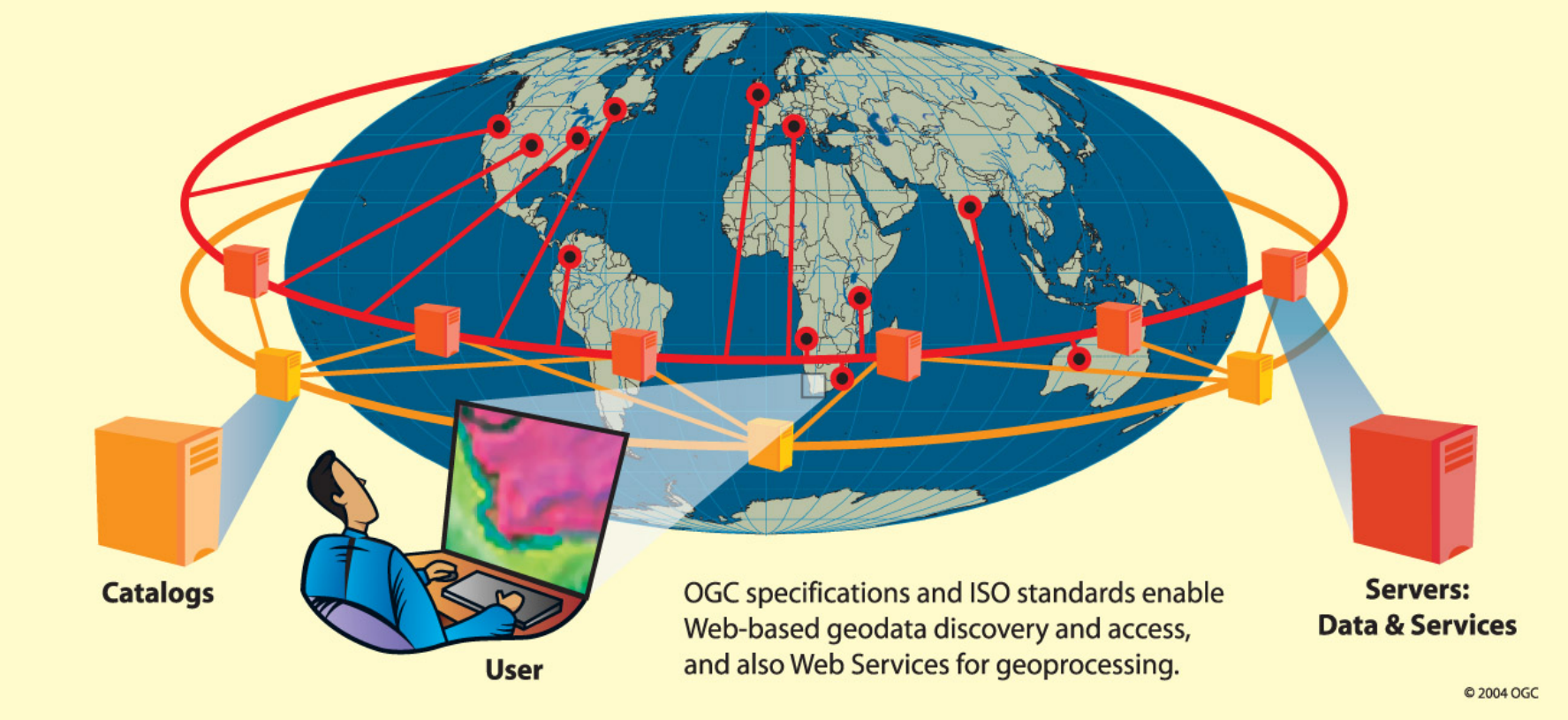
The OGC vision is global



Composed of many collaborating organizations... authoring and publishing open standards for geospatial interoperability

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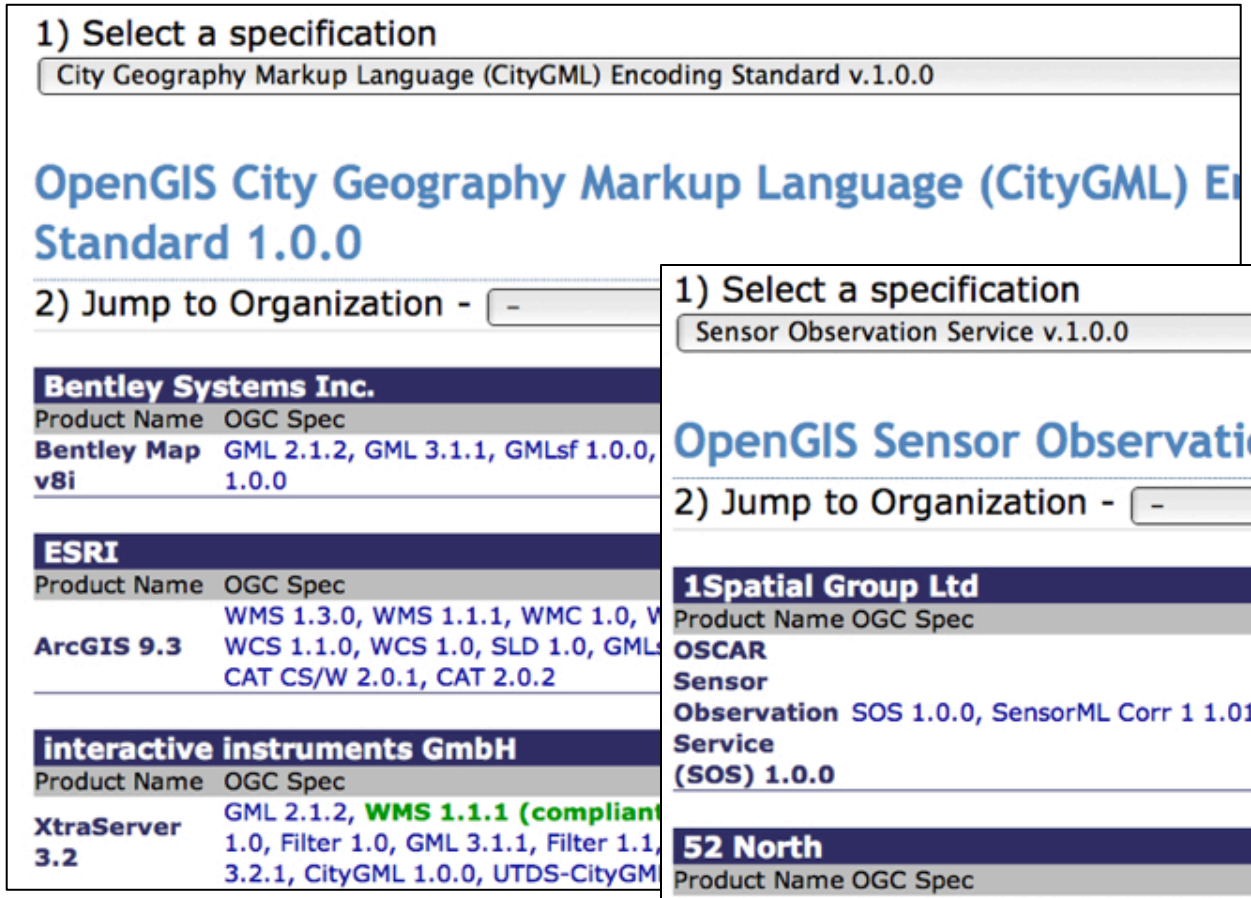
Helping the World to Communicate Geographically

700+ implementing and certified products

http://www.opengeospatial.org/resource/products


1) Select a specification

City Geography Markup Language (CityGML) Encoding Standard v.1.0.0

OpenGIS City Geography Markup Language (CityGML) E
Standard 1.0.0

2) Jump to Organization -

Bentley Systems Inc.

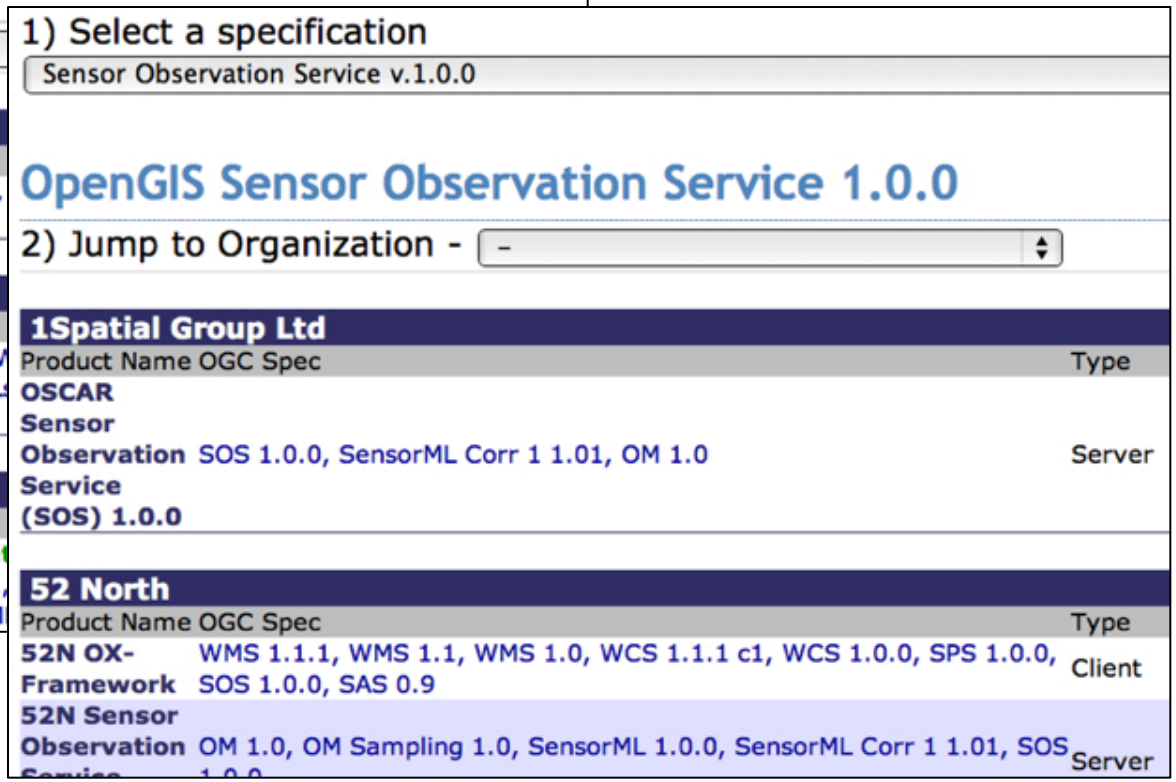
Product Name	OGC Spec
Bentley Map v8i	GML 2.1.2, GML 3.1.1, GMLsf 1.0.0, 1.0.0

ESRI

Product Name	OGC Spec
ArcGIS 9.3	WMS 1.3.0, WMS 1.1.1, WMC 1.0, W WCS 1.1.0, WCS 1.0, SLD 1.0, GML CAT CS/W 2.0.1, CAT 2.0.2

interactive instruments GmbH

Product Name	OGC Spec
XtraServer 3.2	GML 2.1.2, WMS 1.1.1 (compliant 1.0, Filter 1.0, GML 3.1.1, Filter 1.1, 3.2.1, CityGML 1.0.0, UTDS-CityGM


1) Select a specification

Sensor Observation Service v.1.0.0

OpenGIS Sensor Observation Service 1.0.0

2) Jump to Organization -

1Spatial Group Ltd

Product Name	OGC Spec	Type
OSCAR Sensor Observation Service (SOS) 1.0.0	SOS 1.0.0, SensorML Corr 1 1.01, OM 1.0	Server

52 North

Product Name	OGC Spec	Type
52N OX-Framework	WMS 1.1.1, WMS 1.1, WMS 1.0, WCS 1.1.1 c1, WCS 1.0.0, SPS 1.0.0, SOS 1.0.0, SAS 0.9	Client
52N Sensor Observation	OM 1.0, OM Sampling 1.0, SensorML 1.0.0, SensorML Corr 1 1.01, SOS	Server

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Cloud Services

Email Print

DigitalGlobe's Cloud Services unlock the power of the world's largest online library of high-resolution Advanced Ortho imagery. With our extensive suite of OGCcompatible web services combined with our powerful hosting infrastructure, we can instantly deliver current, high-resolution imagery and geospatial information to desktops, portals, intranets and mobile devices around the world.

Delivering the World

With our Advanced Ortho Content Programs, our powerful

Easier Integration

Satellite imagery and metadata are accessible through a full

Resources

Supporting Documents

Cloud Services
Overview of DigitalGlobe's Cloud Services 3.0
> Download

Web Services Available

Web Feature Service (WFS)
- Query against metadata
- Real-time coverage display

Web Map Service (WMS)
- Natively interoperable with most GIS Software
- Images generated upon request per specification

Web Map Tile Service (WMTS)
- Image tiles delivered rapidly
- Renders rapidly for panning and zooming

Web Coverage Service (WCS)
- Easily download GeoTIFFs and other formats
- Perform multispectral analysis and visualization

The World Meteorological Organization (WMO)

‘... the UN system's authoritative voice on the state and behaviour of the Earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting **distribution of water resources**’

‘... facilitates the free and unrestricted exchange of data and information, products and services in real- or near-real time ...’

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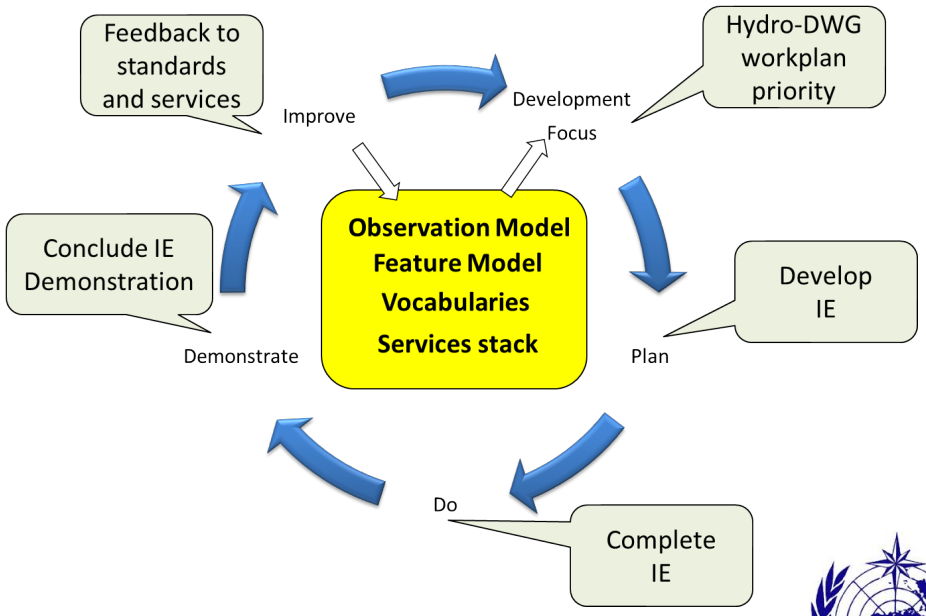
International Standardization for Water Data

- **Hydrology Domain Working Group**
  - standards for water data: **WaterML 2.0 suite**
  - organizing Interoperability Experiments (IEs) focused on different sub-domains of water

- Chairs:
  - Ilya Zaslavsky (USA)
  - Tony Boston (Australia)
  - Silvano Pecora (Italy)

Iterative Development



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http://external.opengis.org/twiki_public/bin/view/HydrologyDWG/WebHome

Hydrology DWG: History

- March 2007
  - CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science, Inc.) submits WaterML as OGC Discussion Paper (Zaslavsky, Valentine, Whiteaker)
- September 2007 (Canberra, Australia)
  - Agreed time was right to establish working group to move forward
- 2008
  - Much discussion between CSIRO, CUAHSI, OGC and WMO
- 2009: OGC/WMO Hydrology Domain Working Group is formed
- 2010-2014: regular meetings, annual workshops, IEs
- 2009: Groundwater IE
- 2010: Surface Water IE
- 2011: WaterML 2.0 SWG established
- 2012: OGC® has adopted the OGC WaterML 2.0 Part 1: Time Series Encoding Standard as an official OGC standard

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Adoption by WMO

- November 2012
  - **Adoption of Resolution 3 at CHy-14**

    "Proposed adoption of WaterML 2.0 as a standard"

    CHy… decides to commence a process…that could see the potential adoption of the WaterML 2.0 as a WMO standard for information exchange managed by WMO (supported by the WMO/OGC Memorandum of Understanding), and to register this standard as a joint WMO/ISO standard…

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HDWG: Selected Past Achievements

- WaterML 2.0 Part 1: Time Series as an official OGC standard
- HY_Features: Common Hydrological Feature Model as an OGC Discussion Document
- WaterML2.0 - part 2: Ratings, Gaugings and Sections as an OGC Discussion Document
- WaterML-WQ - an O&M and WaterML 2.0 profile for water quality data as an OGC Best Practice Document
- Sensor Observation Service 2.0 Hydrology Profile" as an OGC Best Practice Document
- Numerous IE's (Groundwater, Surface Water, Water Quality…)
- Participation in several cross-domain projects (AIP's, OWS's, CHISP-1 (Climatology-Hydrology Information Sharing Pilot), etc.
- Platform for showcasing numerous activities in the water and related domains
- …list too long to mention everything

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HDWG: tasks ahead

- Standard development - WaterML2.0 - part 2: Ratings, Gaugings and Sections
- Standard development – RiverML (Channel and floodplain geometry)
- Standard development GroundWaterML2
- Standard development WaterML2-WaterQuality
- Standard development HY_Features
- Get IE's going (Forecasting, gaugings and ratings…)
- Addressing a Water Suite of standards
- Many other issues waiting for champions to take them further…

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Suite of Water Information Standards

HIC-11 Tutorial: Standardization of Water Data Exchange

WMO/OGC Hydrology Domain Working Group

Irina Dornblut, GRDC of WMO at BfG

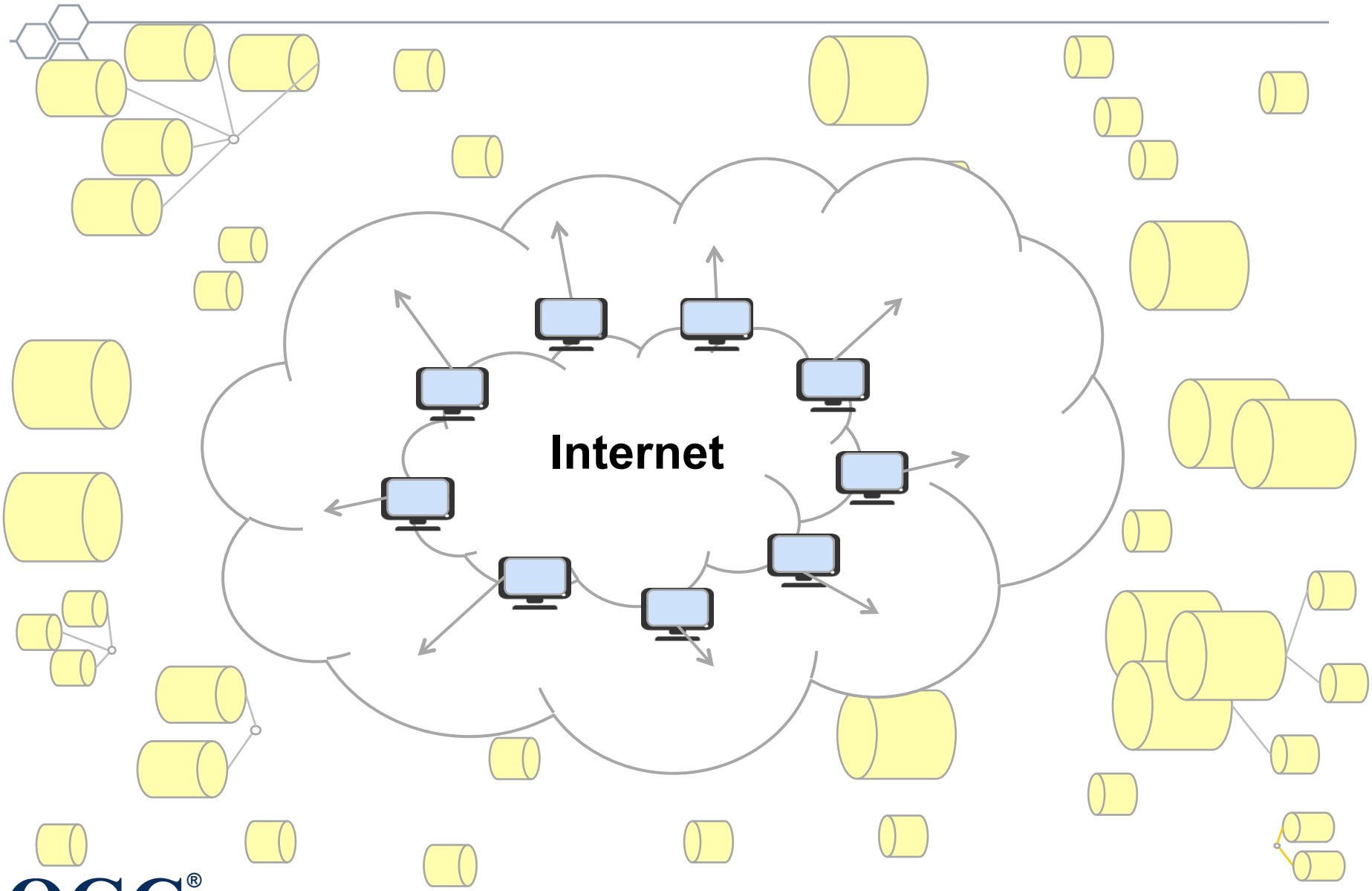
New York, CCNY, August 16, 2014

OGC®
Making location count.

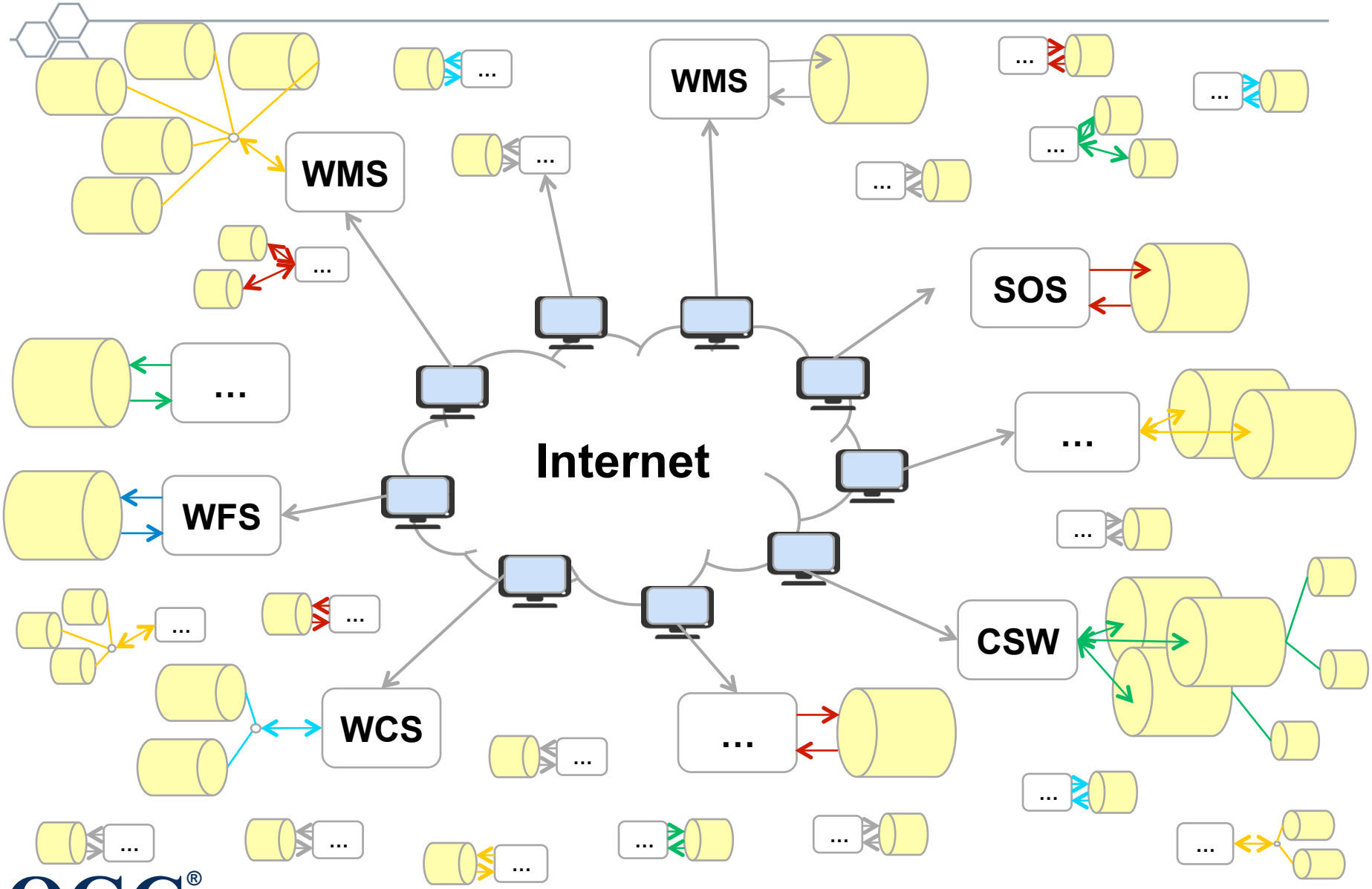
GRDC

WMO OMM

Hydrologic data via Web services



Hydrologic data via Web services



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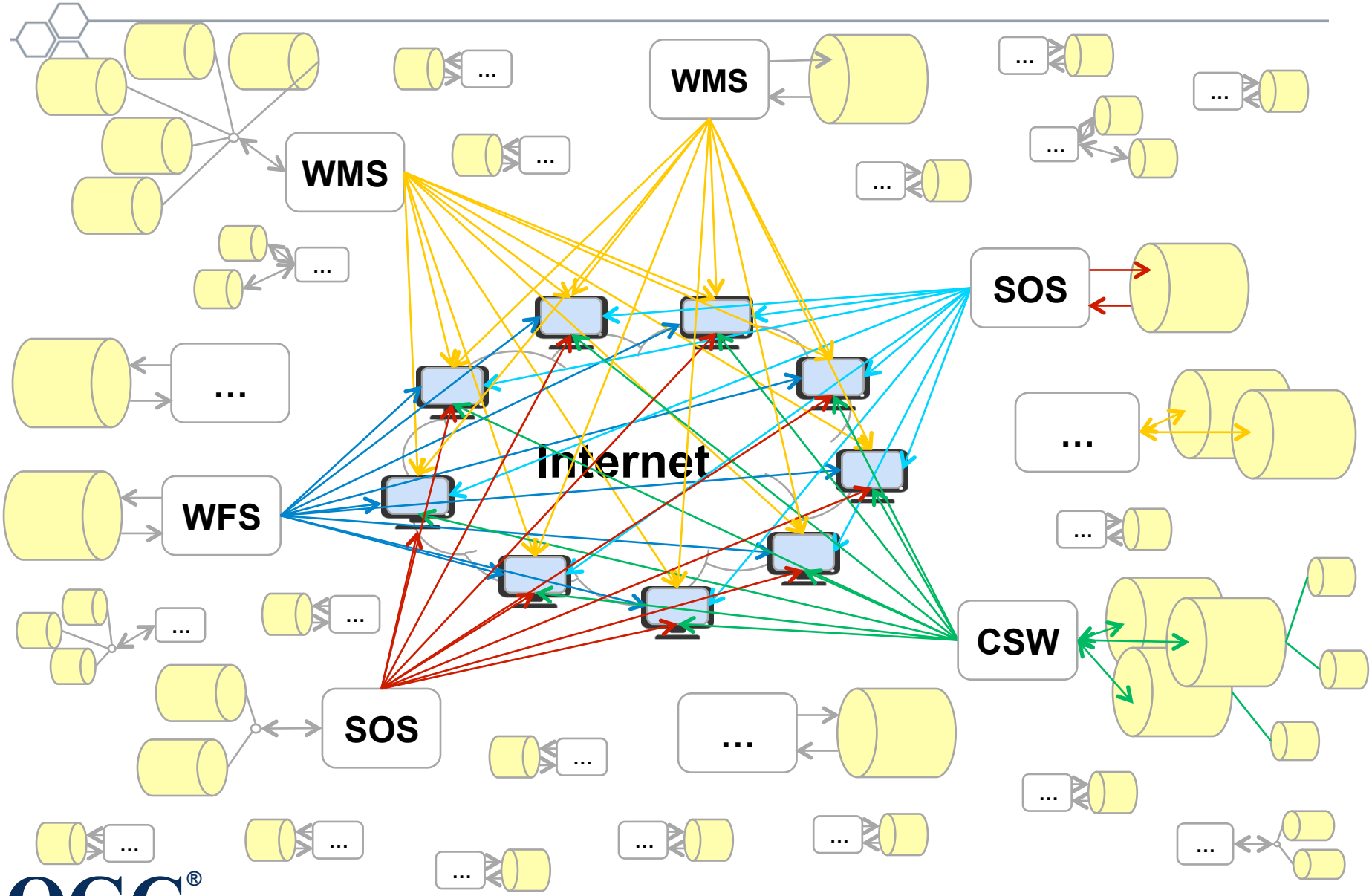
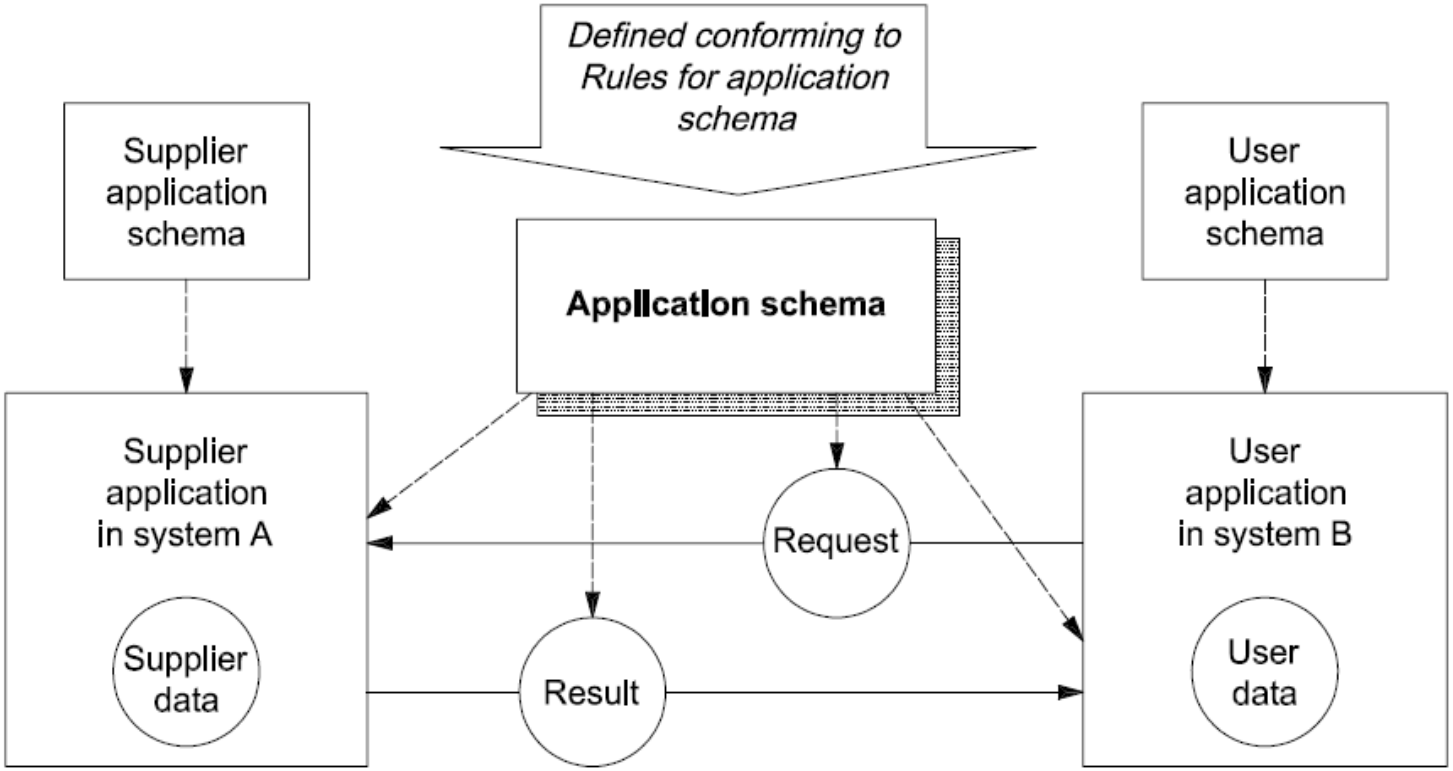


Suite of Water Information standards

Interoperability ensures communication among Web services.

Rules for application schemas ensure interoperability between technical systems.

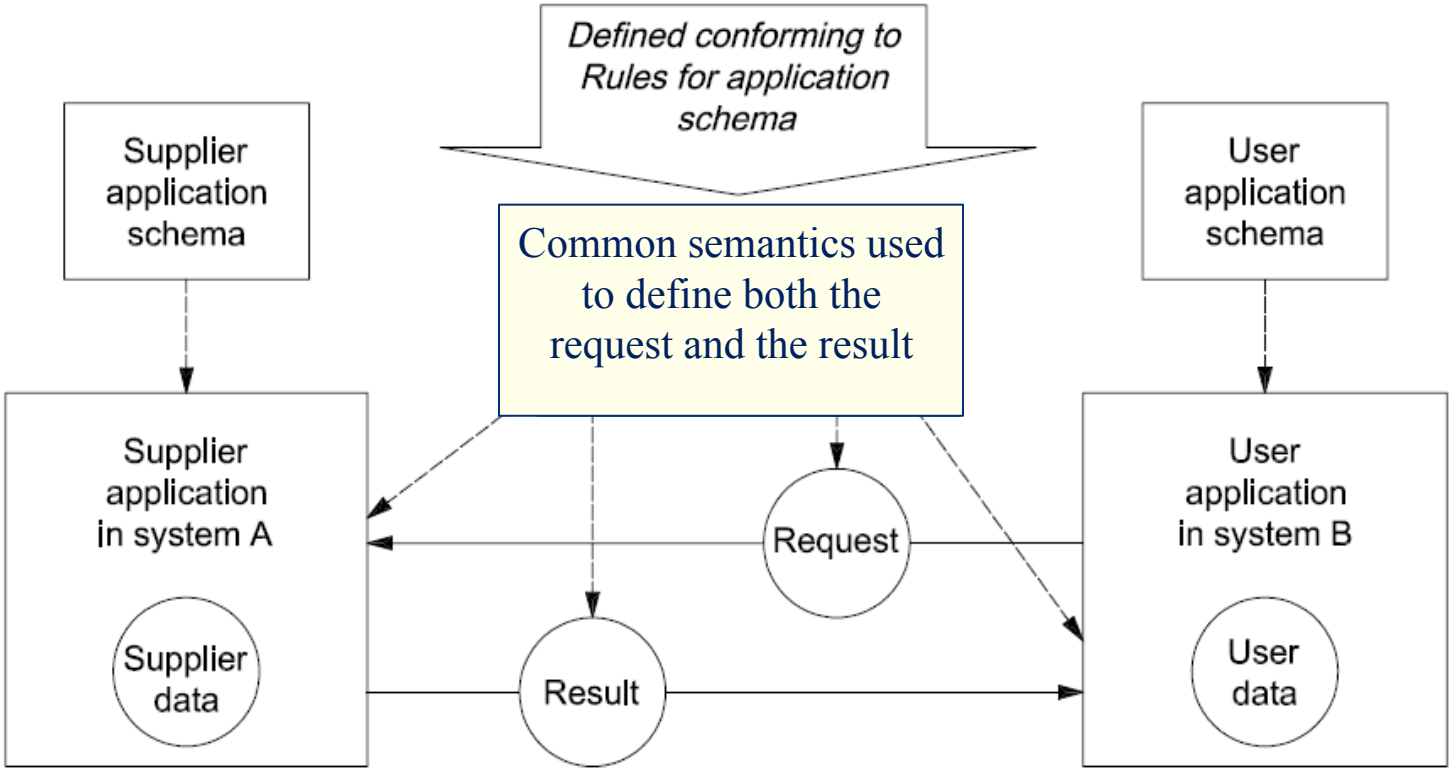
Water data exchange using standards



NOTE The unbroken lines show the flow of data. Broken lines denote the role of the application schema on the data interchange.

[ISO19109:2005, **Figure 2**]— **Data interchange by transactions**

Water data exchange using standards



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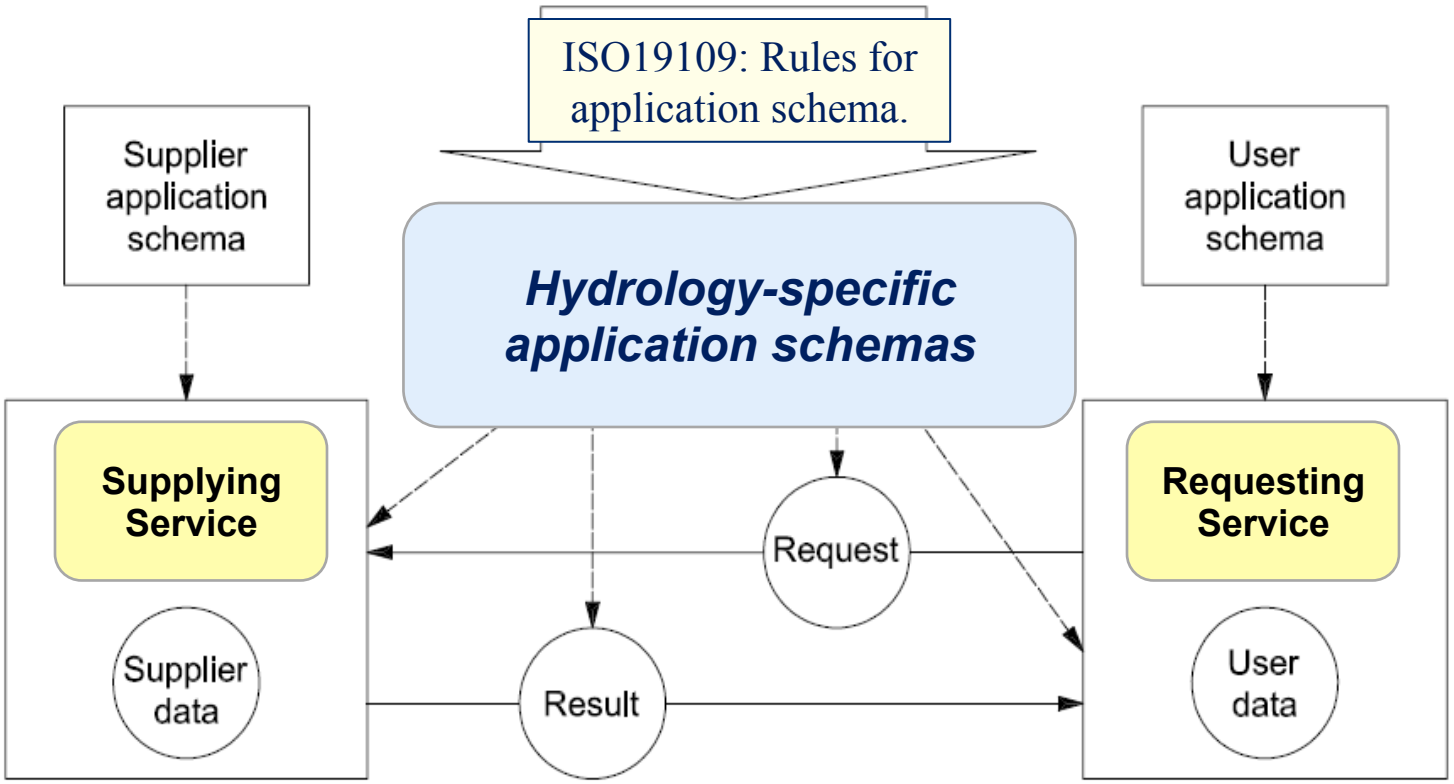

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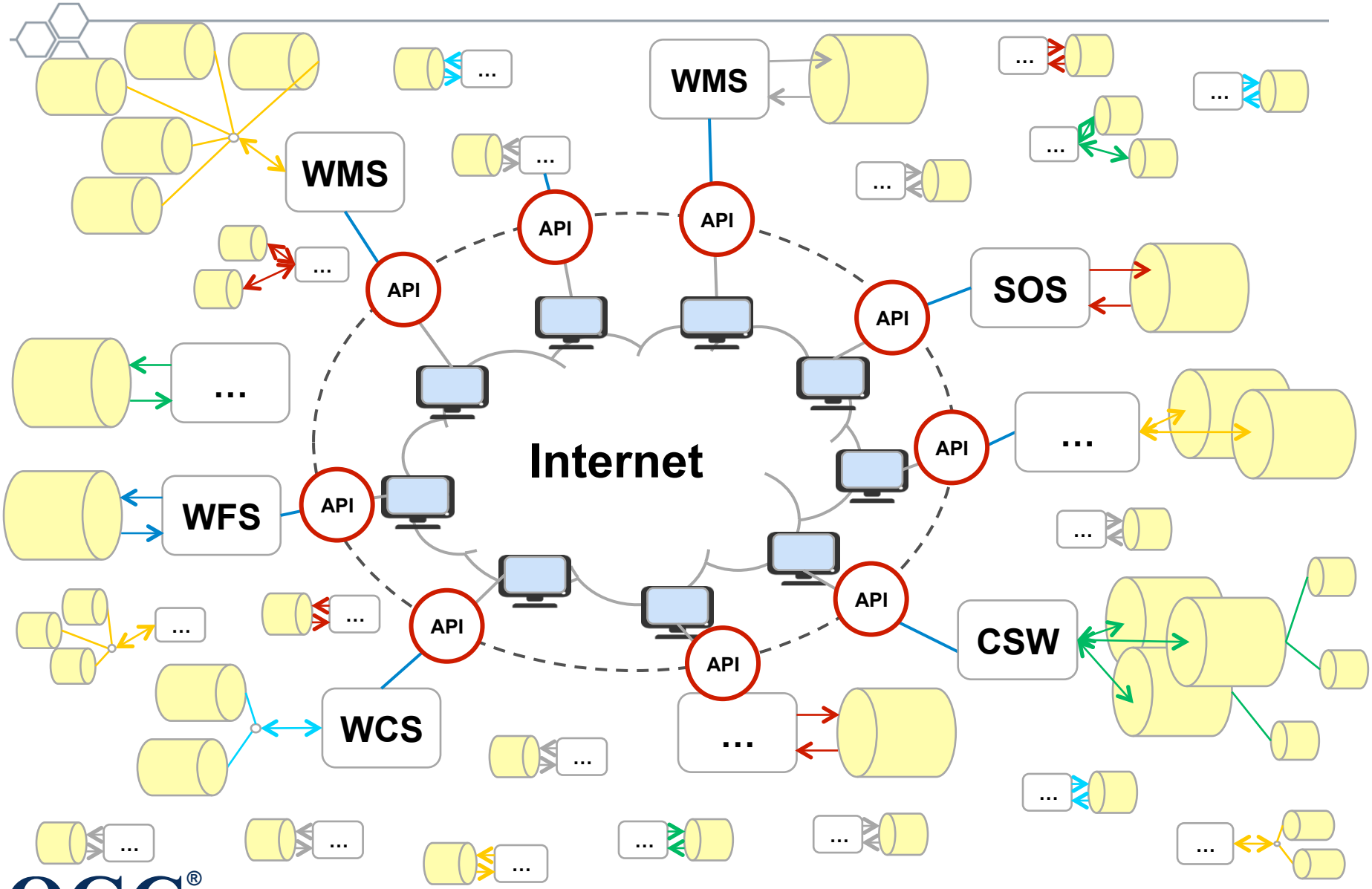
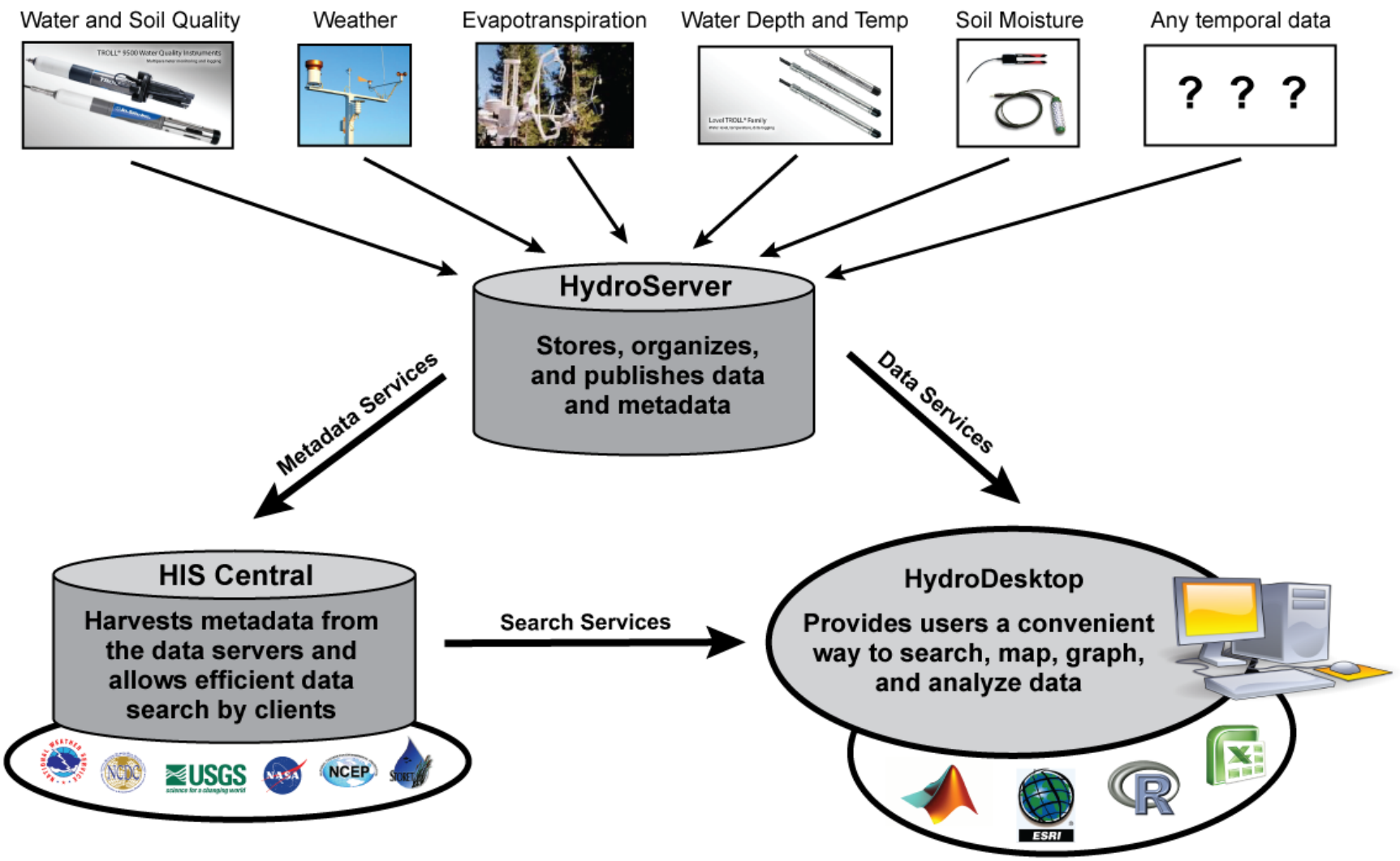
[ISO19109:2005, **Figure 2**]— **Data interchange by transactions**

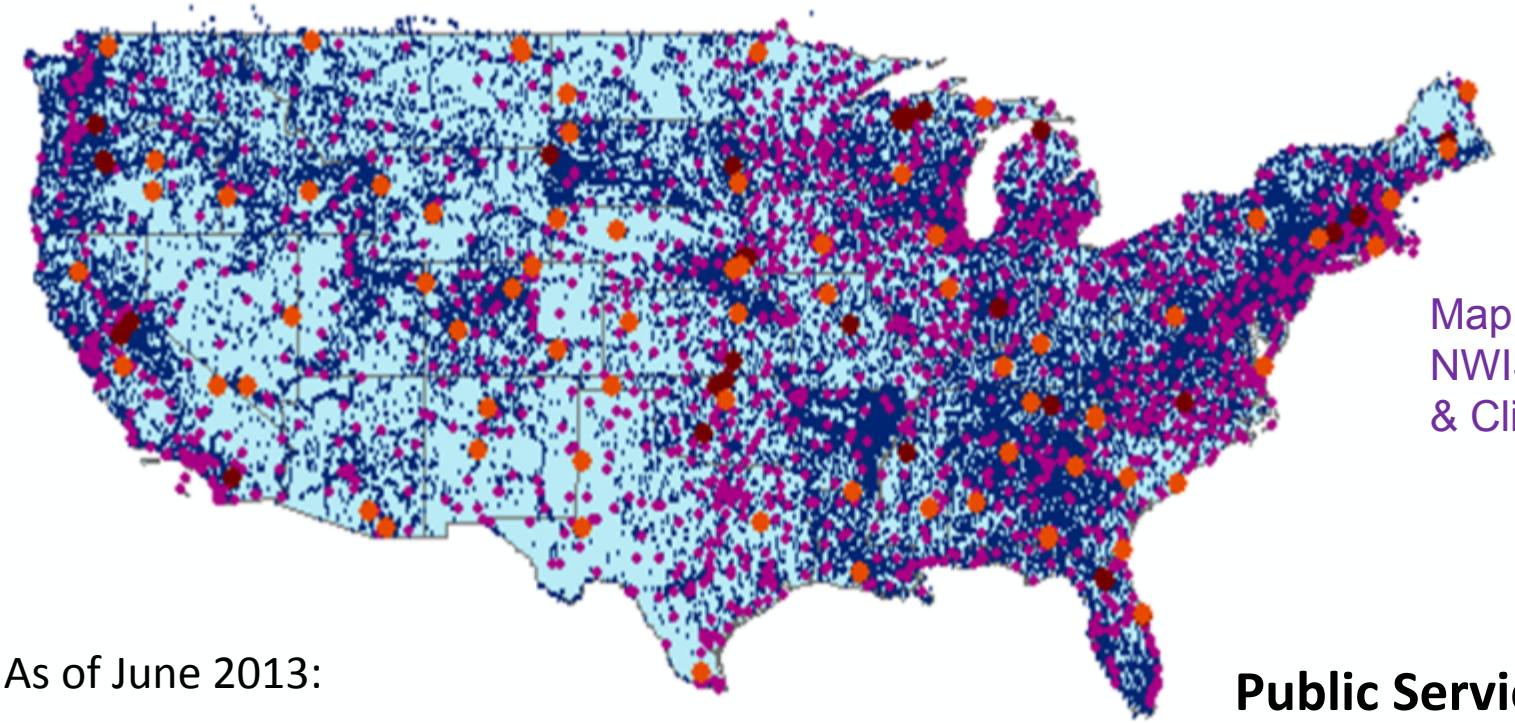
Technical interoperability of Web services



CUAHSI Hydrologic Information System



HIS HydroCatalog Content



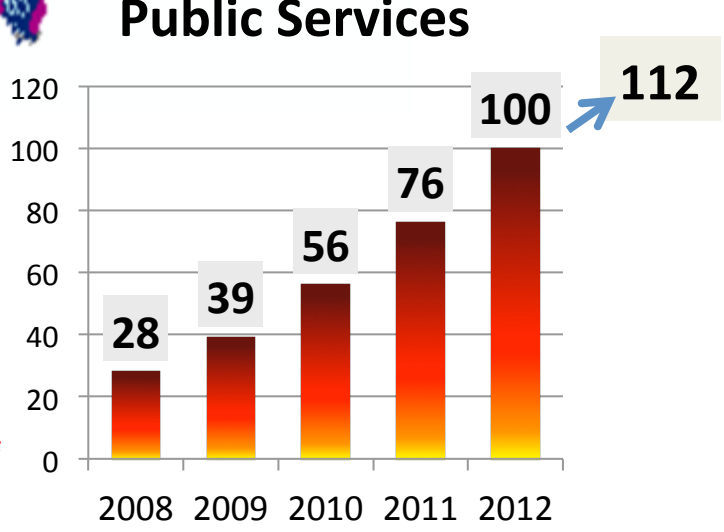
Map integrating NWIS, STORET, & Climatic Sites

As of June 2013:

100+ public services
32.8 thousand variables
3.25 million sites
28.9 million series
Referencing 340+ billion data values

Available via HISCentral discovery services

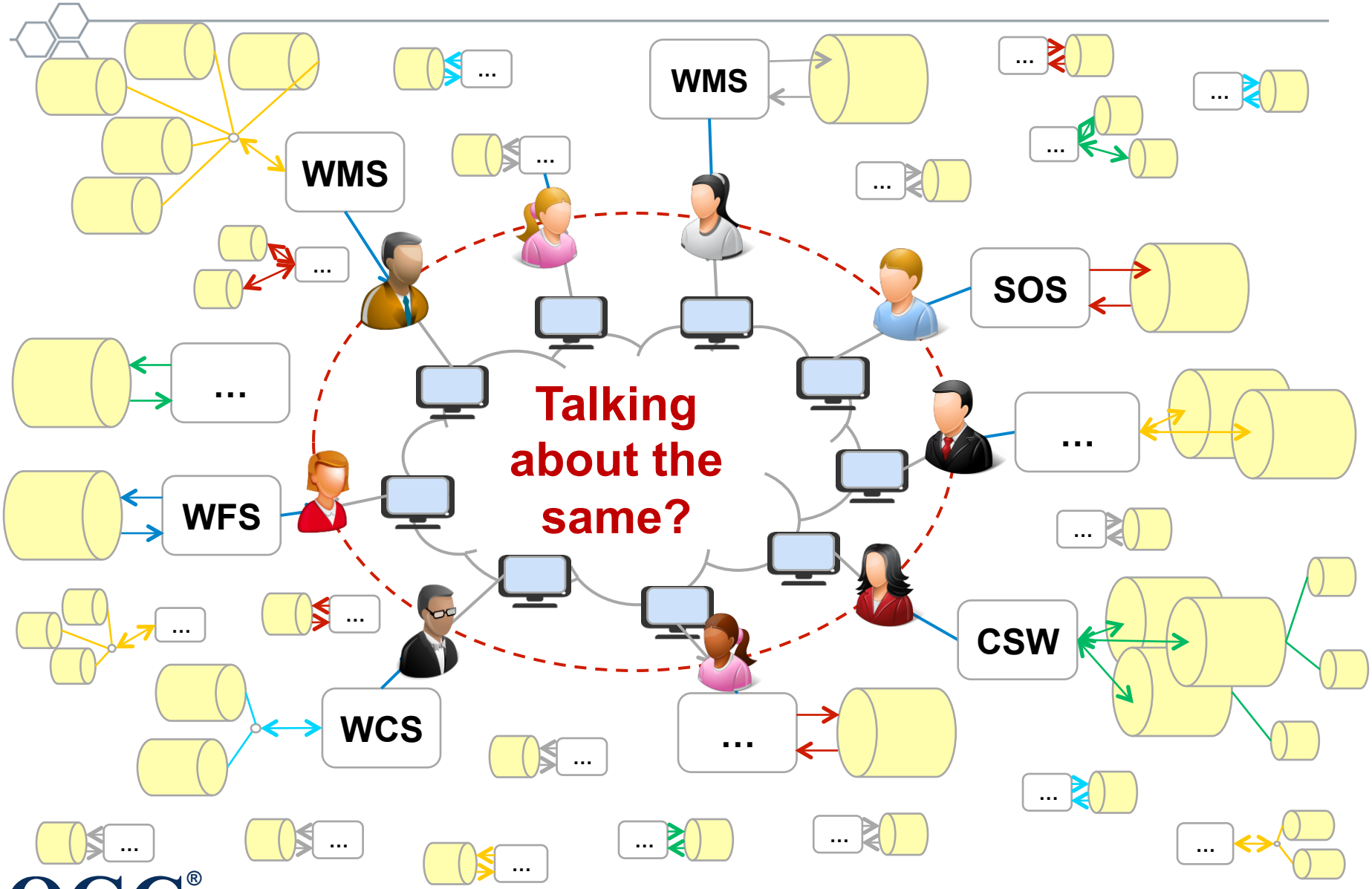
Available via GetValues requests



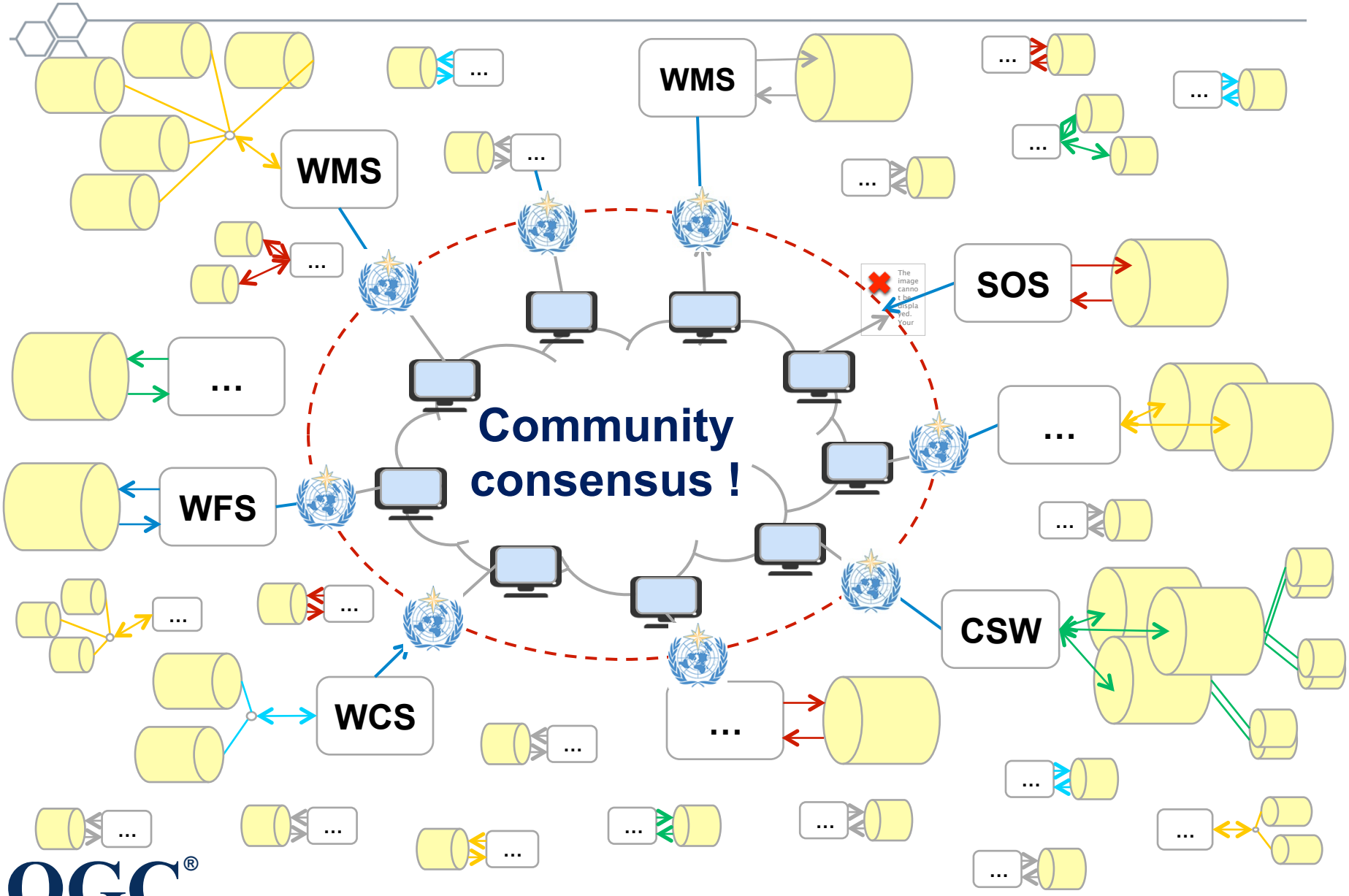
Semantic interoperability between Web services

- Concerned with understanding the context and correct meaning of exchanged information
- Requires representation of context (e.g. ontology) and concepts (terms)
- May be achieved by linking references
  - Referencing shared concepts within a community / domain
  - Using an reference model / ontologies as mediator between conceptually overlapping perspectives (mapping semantics)
  - Mapping corresponding ontologies, assisted by a set of formal mapping rules based on the description logic of Semantic Web (semantic mapping)

Semantic interoperability of Web services



Semantic interoperability of Web services



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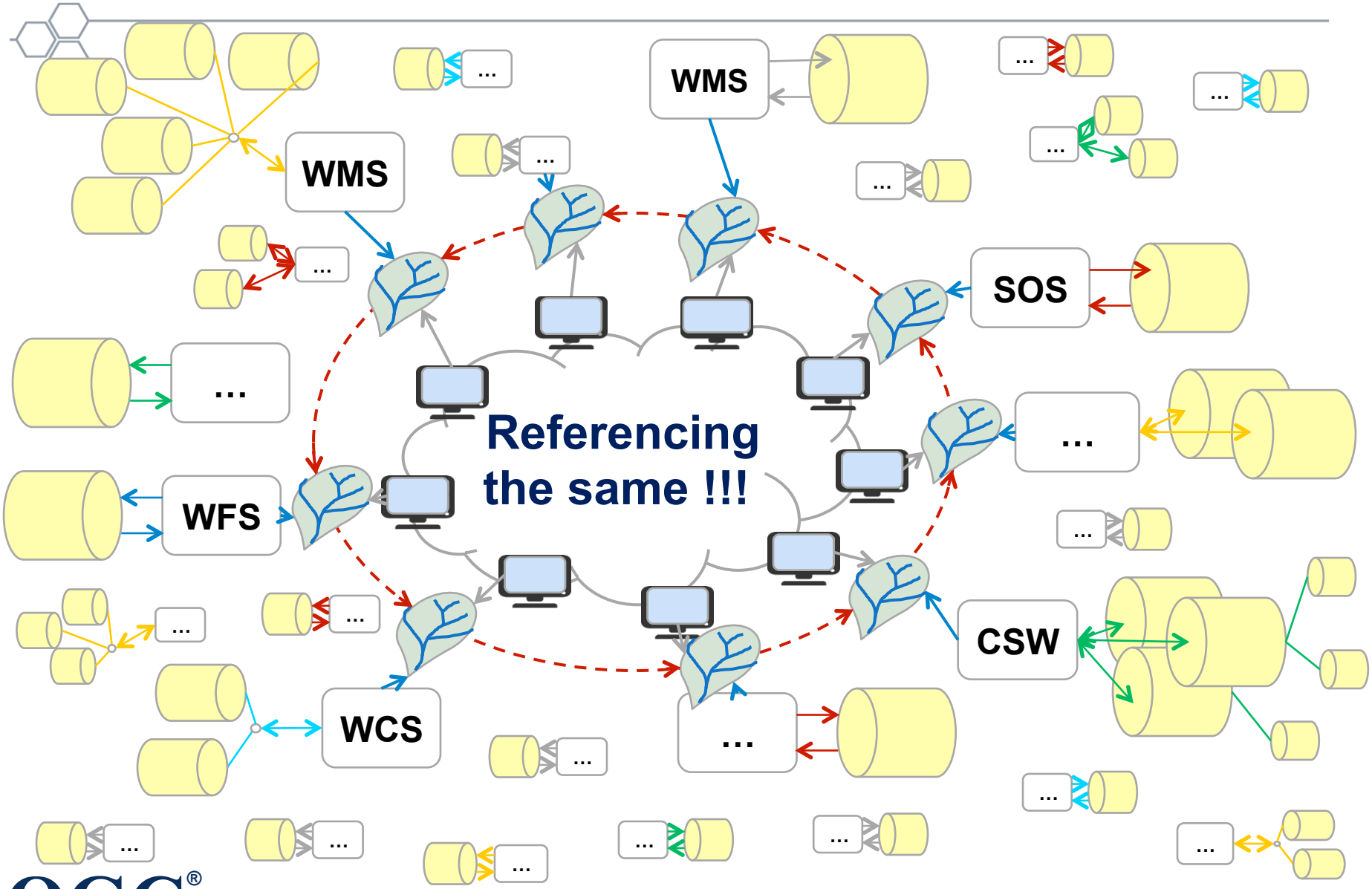

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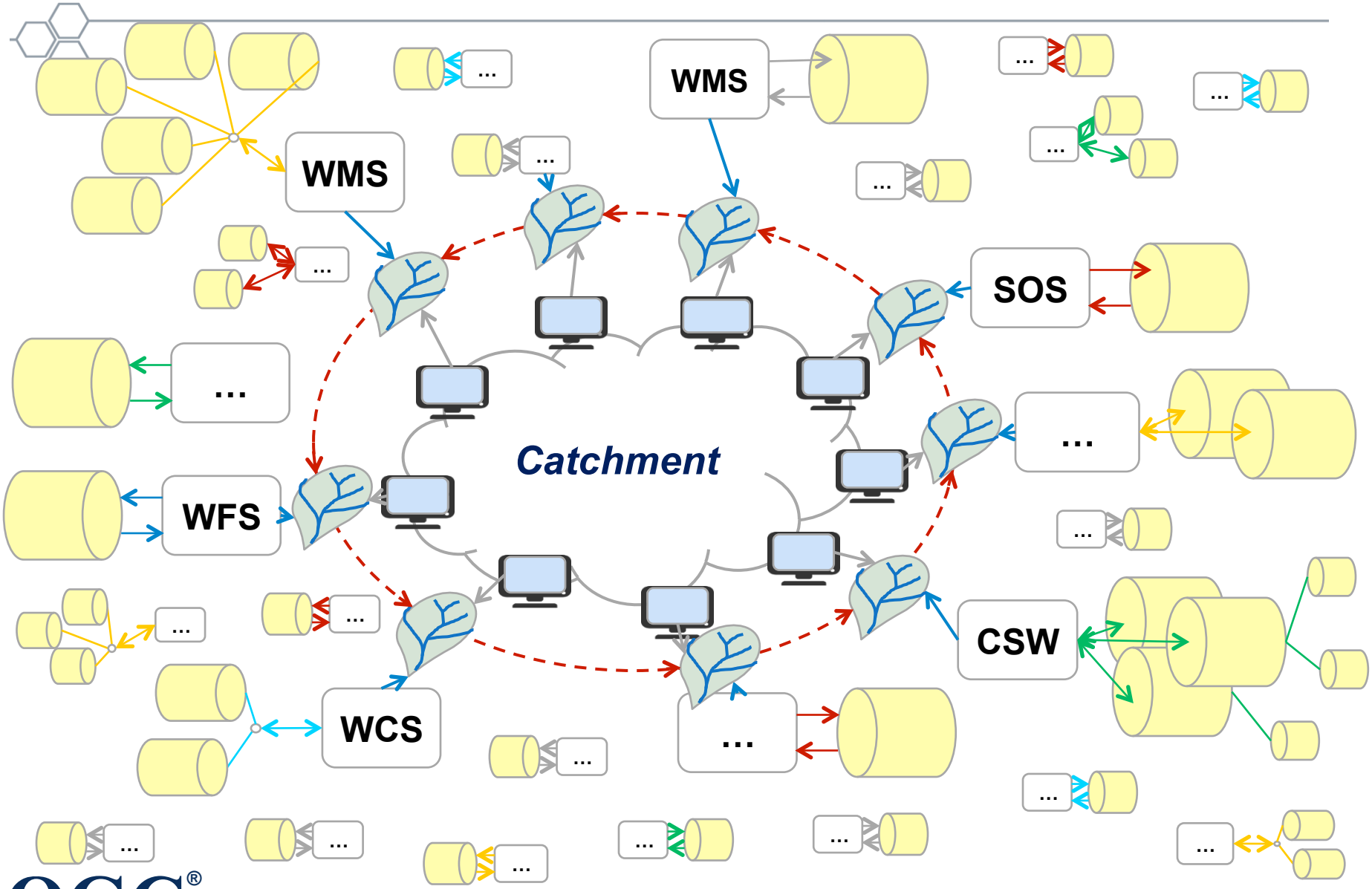


Suite of Water Information standards

Consensus on context and meaning requires mediation by referencing shared concepts.

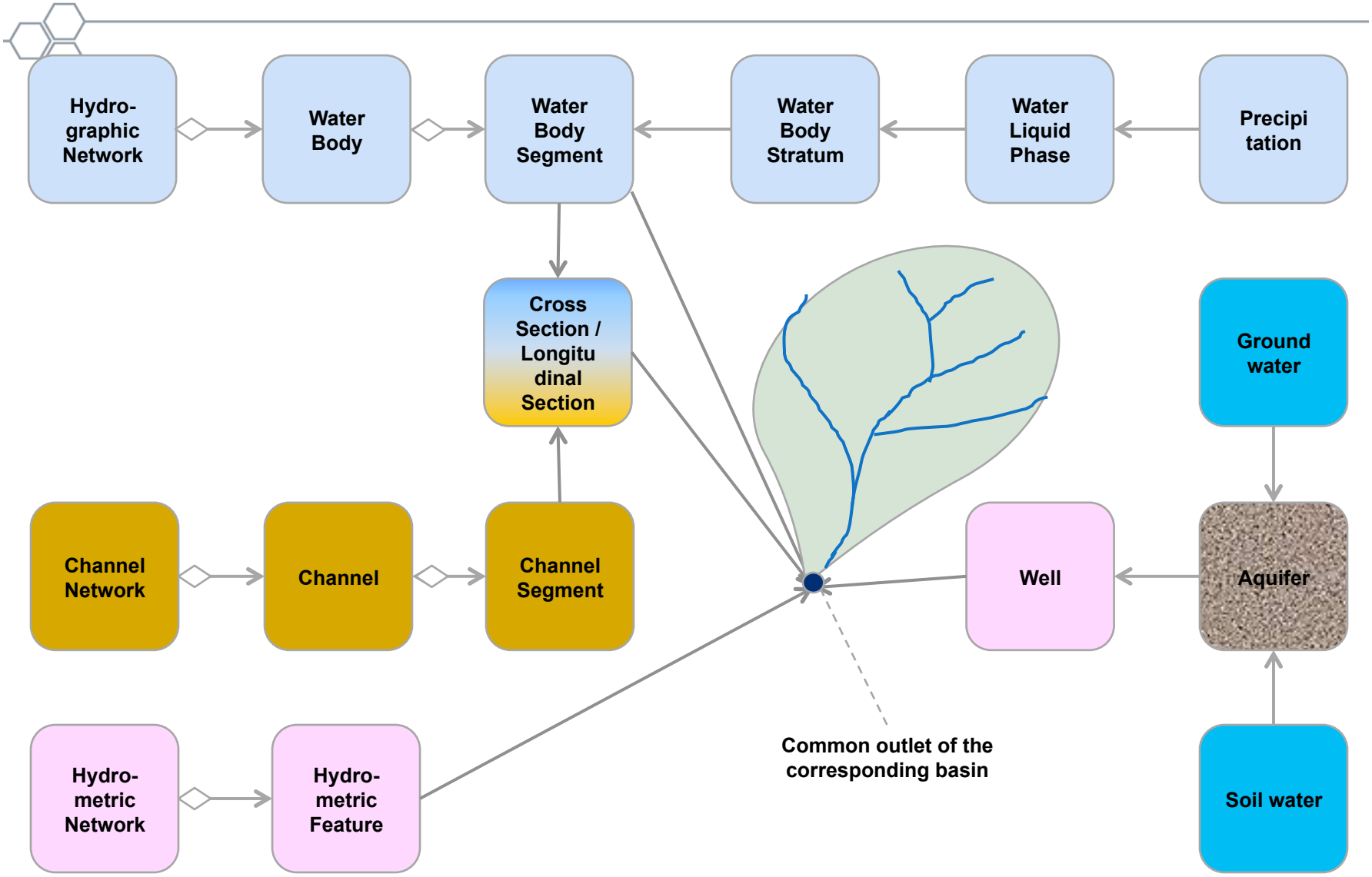
Common concepts mediate among overlapping concepts and multiple representations.

HY_Features, common hydrologic feature model

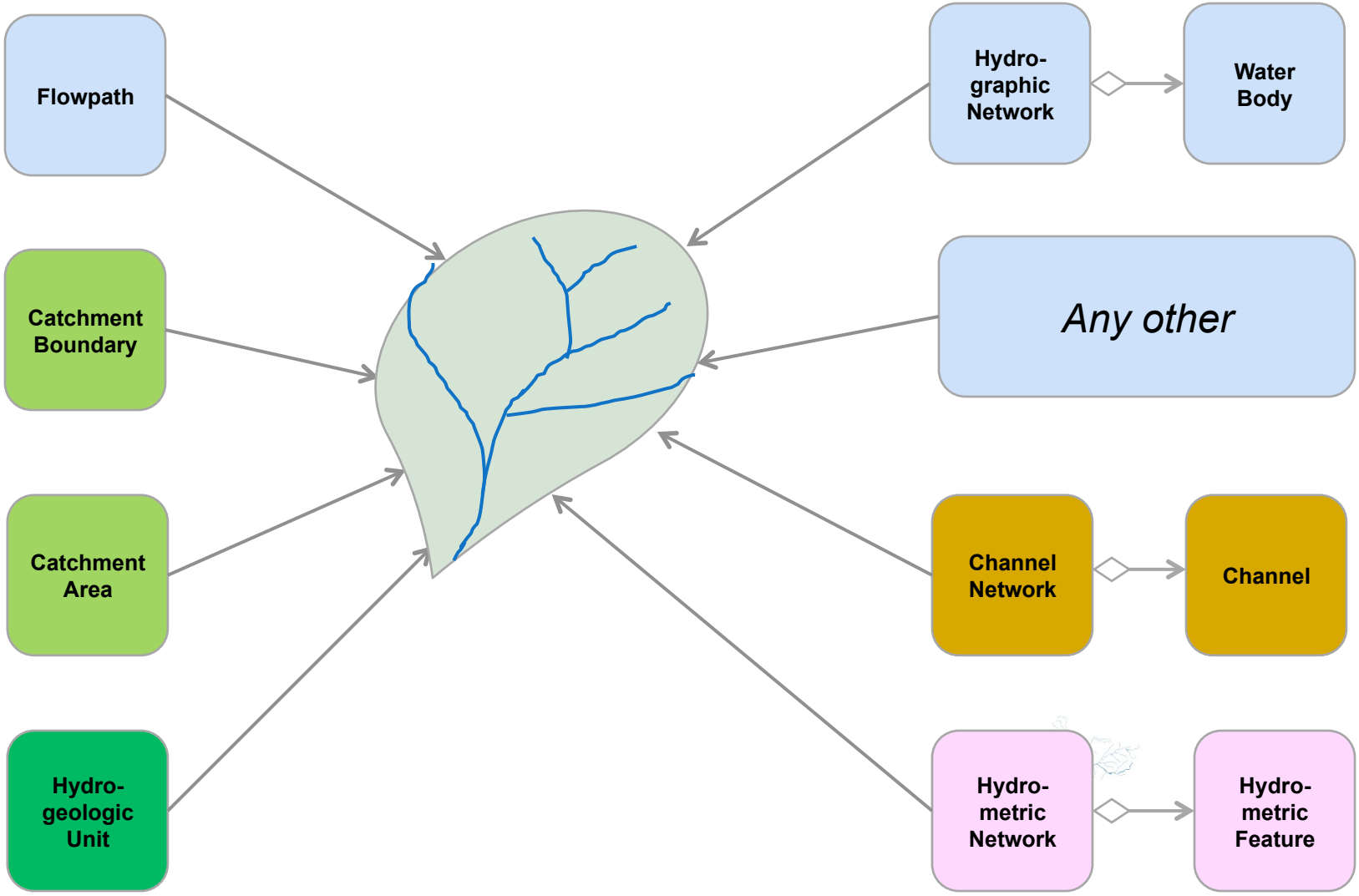
HY_Features, common hydrologic feature model

- describes major components of the hydrosphere and their fundamental relationships incl. a segmentation of watercourses,
- concepts which reflect hydrologic significance and network connectivity,
- compatible concepts, based on definitions endorsed by WMO-CHy (documented in "WMO International Glossary of Hydrology")

HY_Features, hydrosphere objects related to the basin outlet

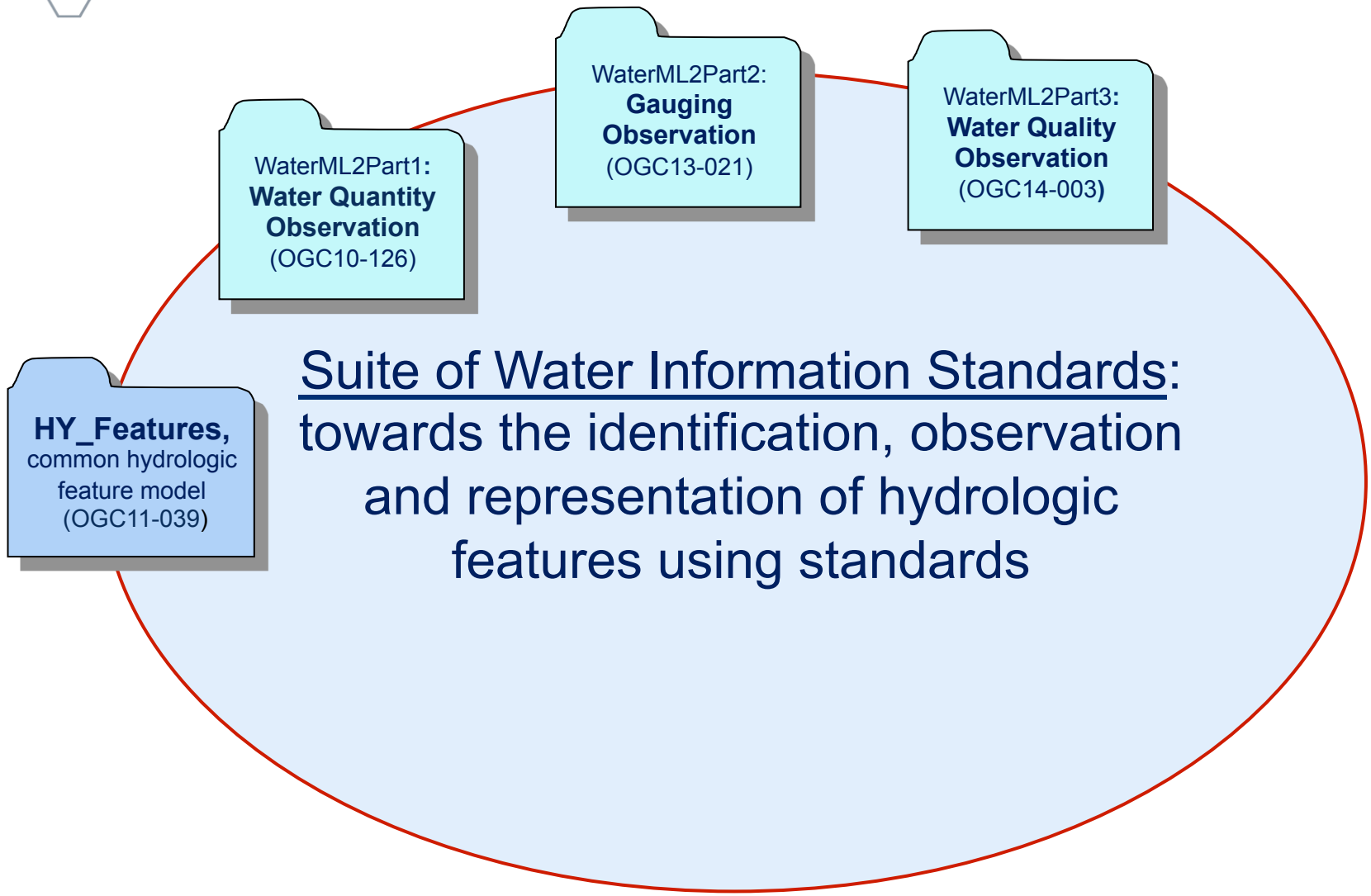


HY_Features associates datasets with the represented basin



http://59.120.223.164/hydro/

WMO/OGC Hydrology Domain Working Group



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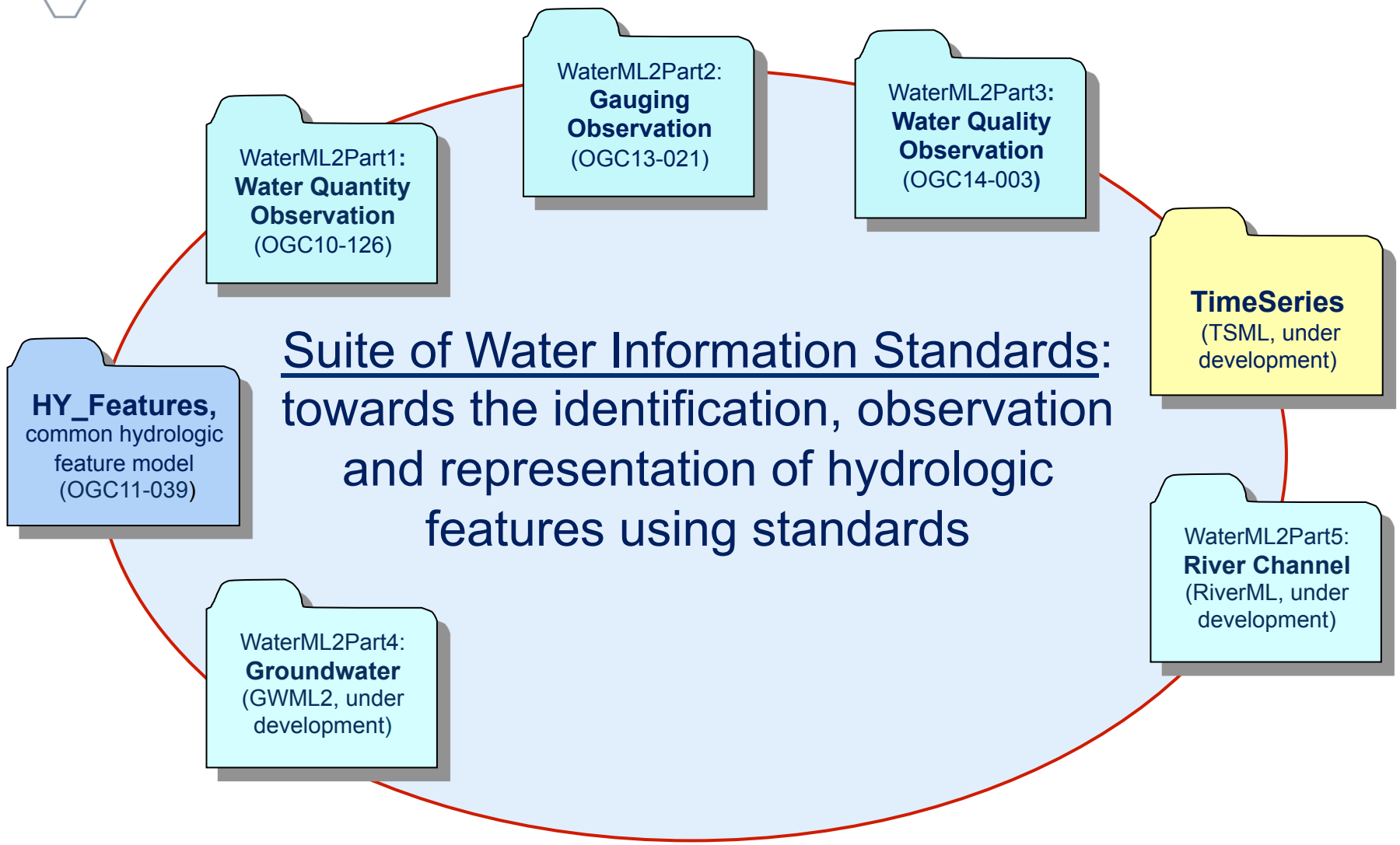
WMO/OGC Hydrology Domain Working Group



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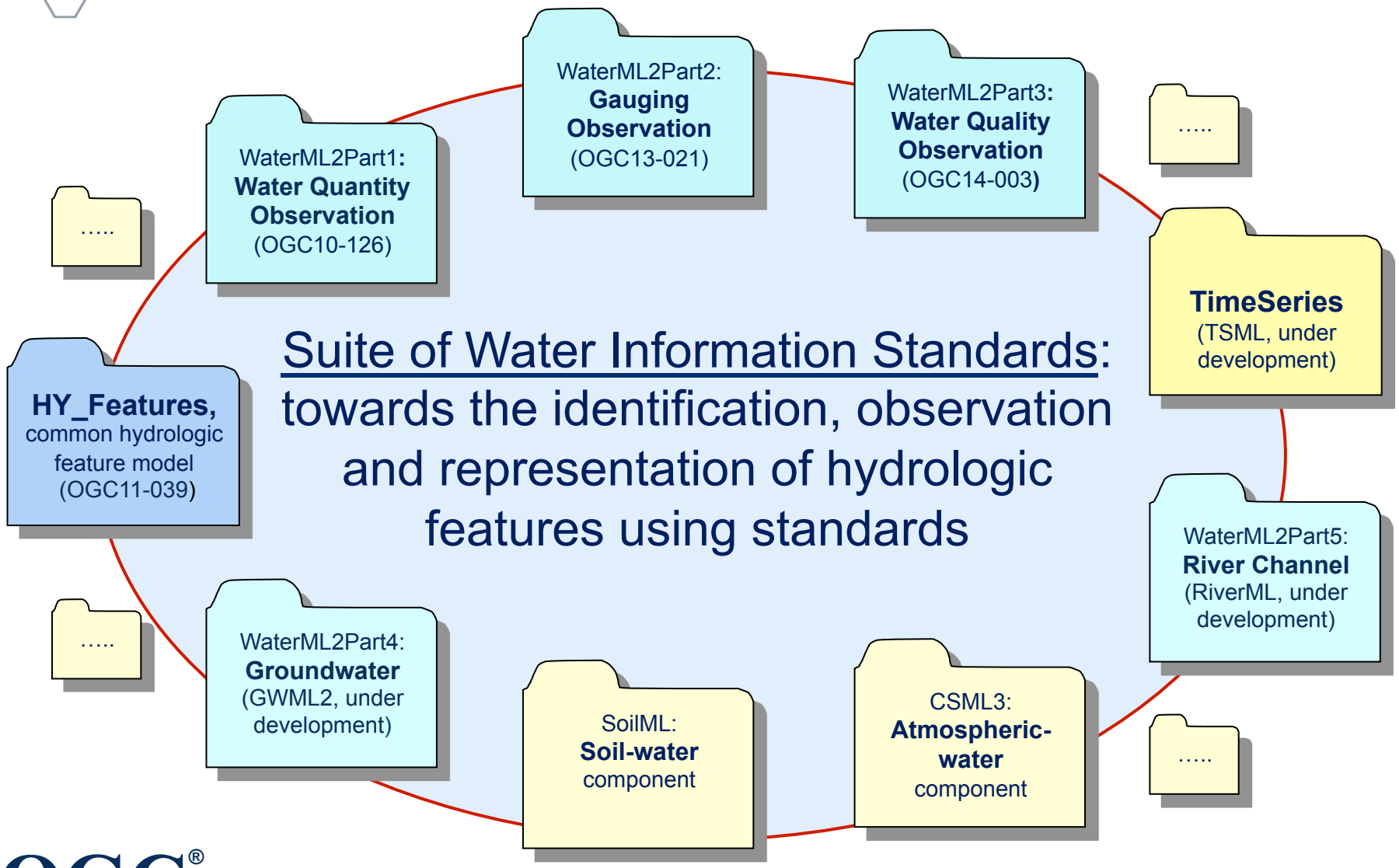
WMO/OGC Hydrology Domain Working Group



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WaterML2.0 (Optional Section)

WaterML2.0 is an interoperability contract that facilitates data exchange.

- A conceptual model expressed in UML
- An XML schema

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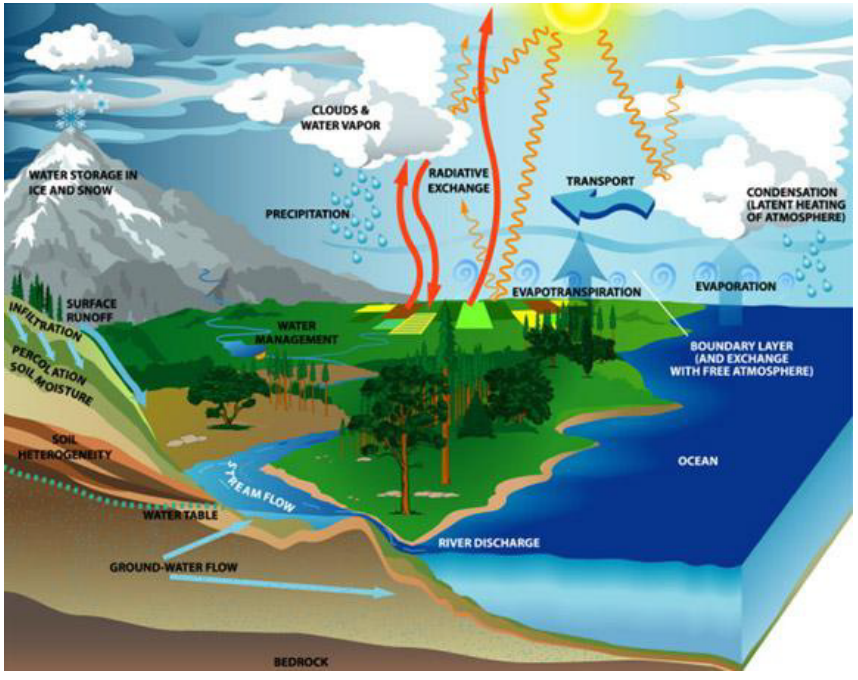
Hydrological observations

Broad categories of water observations

1. In-situ, fixed observation style
2. In-situ, manual observations
3. Ex-situ, complex processing observations
4. Remote-sensed observations
5. Complex data products

Generally, the more complex the process of making the measurement, the less likely it is to be available as a continuous observation.



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Concepts harmonisation

- Discussion Paper
  - Harmonising Standards for Water Observation Data (OGC 09-124r2)

- Considered data exchange formats from:
  - Australian Water Data Transfer Format
  - WaterML1.0
  - XHydro
  - UK Environmental Agency time series data exchange
  - Climate Science Modelling Language
  - Ground Water Mark-up Language (GWML)
  - INSPIRE Hydrography model
  - GRDC Hydrologic Datasets - metadata
  - Integrated Ocean Observing System (IOOS)
  - Marine Metadata Interoperability
  - Sandre - Surface Water Quantity exchange
  - OpenMI
  - FEWS PI

O&M Feature mapping

Hydrological term	ISO19156 – Observations & Measurements
Monitoring station, gauging station, site	SF_SamplingPoint
Borehole, observation well, river profile	SF_SamplingCurve
River cross-section	SF_SamplingSurface

XML schema overview

- Collection
- MonitoringPoint
- ObservationProcess
  - ObservationMetadata
- Timeseries
  - MeasurementTimeseries
    - MeasurementTimeseriesMetadata
  - CategoricalTimeseries
  - TimeseriesMetadata
- TimeValuePair
  - TVPMetadata
  - MeasurementTVP
    - TVPMeasurementMetadata
  - CategoricalTVP

Time series data

Is it all about the dots on a graph?

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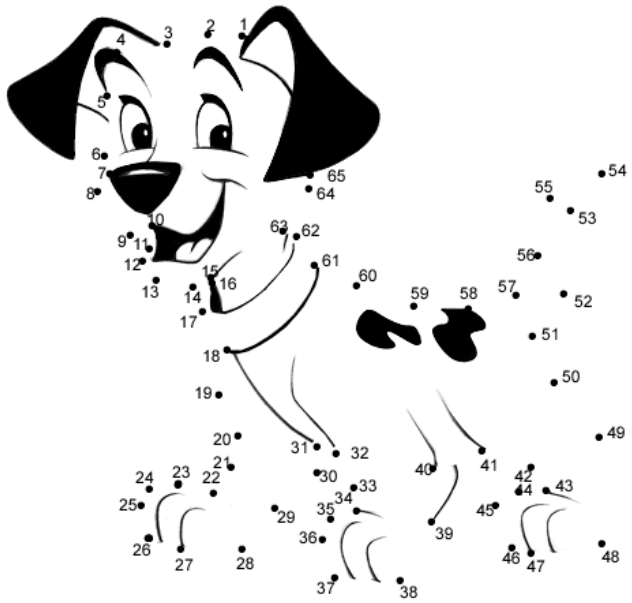
Discrete observations

- The discrete observation is an accurate observation of a feature at a particular point in time.
- The observation is a stand alone item, it is not related to other results.
- Typically ex-situ analysis



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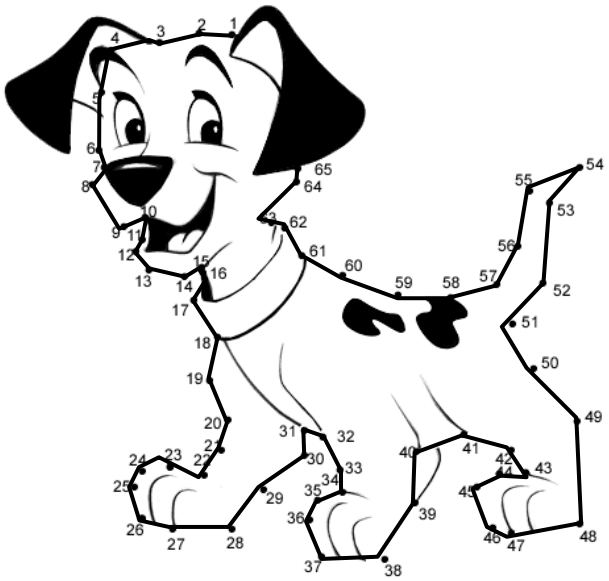
Continuous observations

- Results are collected with a time resolution at which it is appropriate to consider the record to be a continuous representation of the observed phenomena.
- The high data density allows users to fill in the gaps between the observations (dots).

Time series data is not about the dots, its about the lines.



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Time series point metadata

- quality
- nilReason
- comment
- qualifier
- processing
- source
- censoredReason
- accuracy
- interpolationCode
- aggregationDuration

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By point, or set the default for the series

Interpolation code

- Its all about the lines….

- Continuous/Instantaneous
- Discontinuous
- Instantaneous total
- Average in preceding interval
- Maximum in preceding interval
- Minimum in preceding interval
- Preceding total
- Average in succeeding interval
- Succeeding total
- Minimum in succeeding interval
- Maximum in succeeding interval
- Constant in preceding interval
- Constant in succeeding interval
- Statistical

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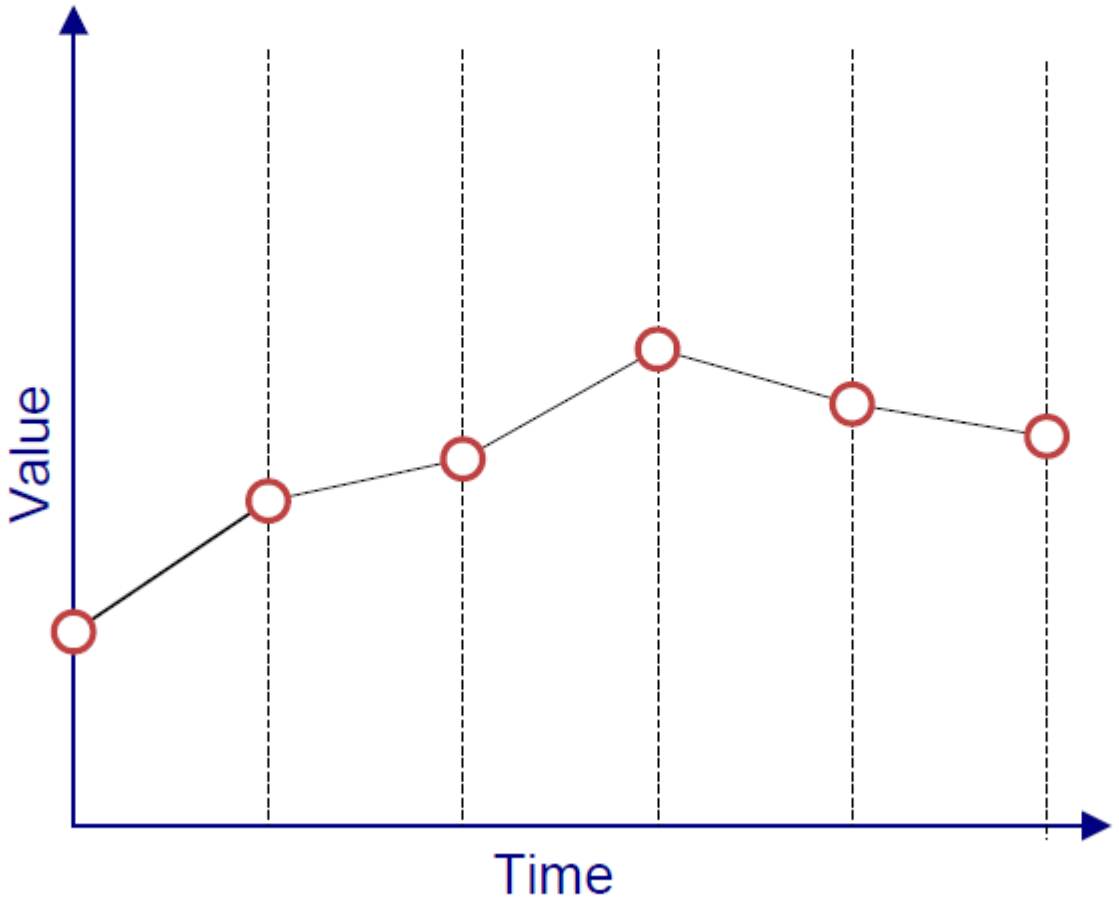
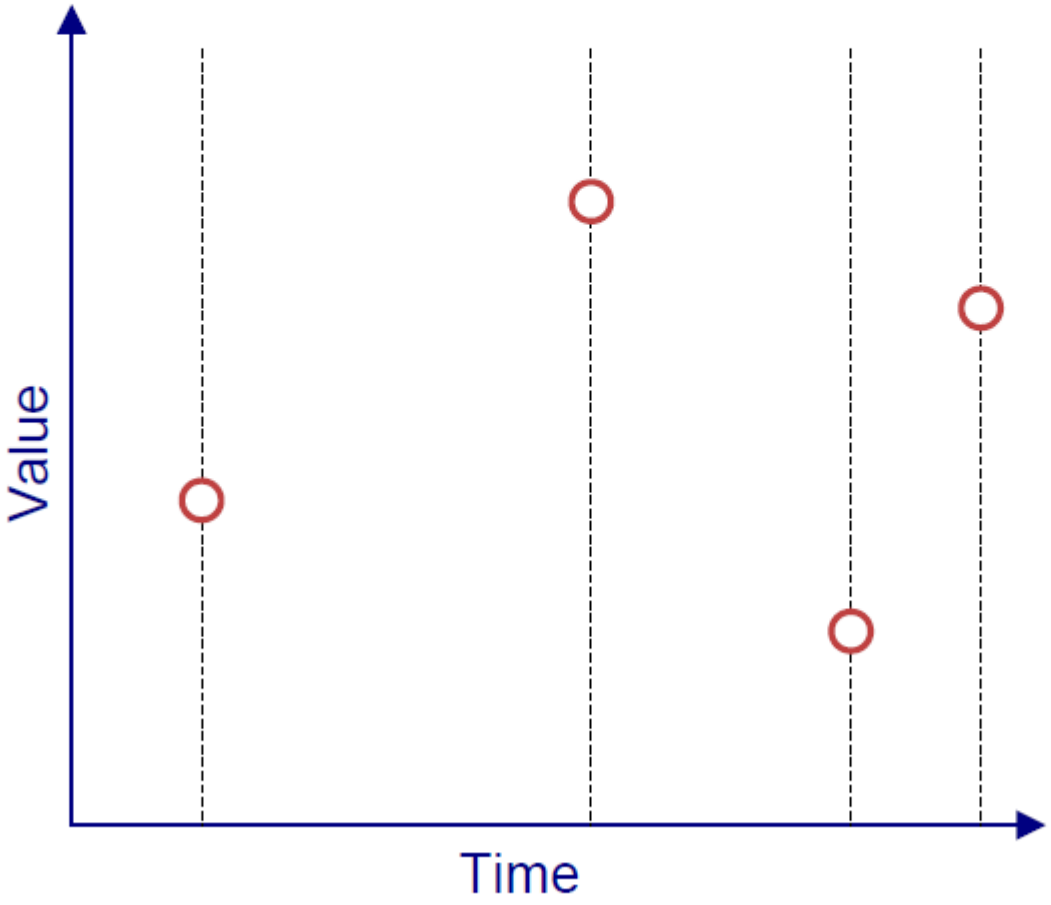
Continuous/Instantaneous



Discontinuous



The following may not be suitable for all users.

<It contains=“explicit”> material <It/>

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            <swe:value>1.0</swe:value>
          </swe:Quantity>
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```

```
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      <sams:shape>
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        </gml:Point>
      </sams:shape>
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      </om:procedure>
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vocabulary

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- Assessing standards compliance (Optional)

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Community Inventory of EarthCube Resources for Geoscience Interoperability

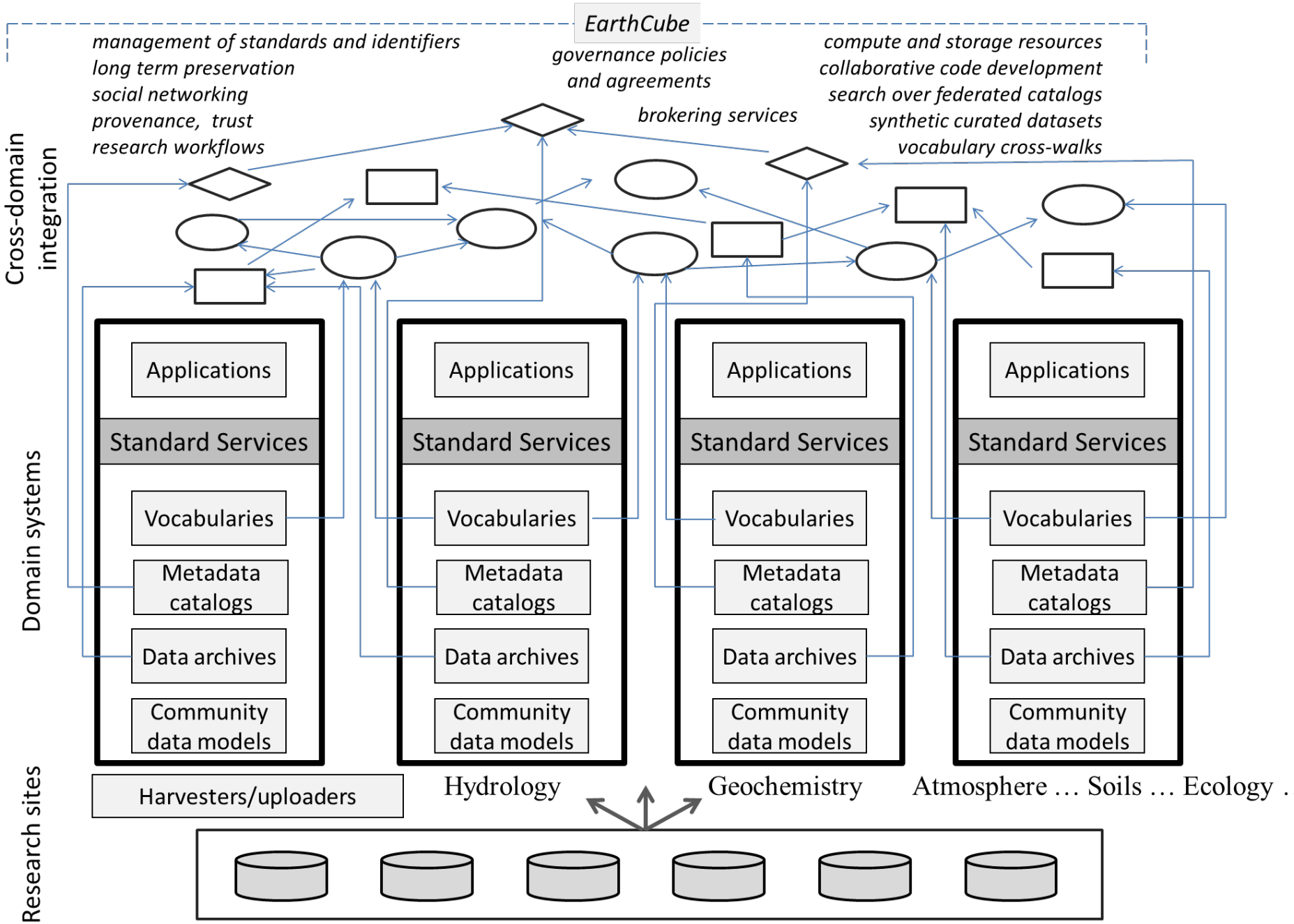
CINERGI

data discovery is the most often cited issue in executive summaries on the EarthCube web site

http://workspace.earthcube.org/cinergi

Goals

- **Large inventory of high quality information resources across disciplines, with traceable provenance, usable across EarthCube research scenarios:**
  - datasets, catalogs, vocabularies, information models, services, process models, repositories, etc.
- **Make it open to the community**
- **Organize it to enable search and integration across domains and linking between information objects**
  - Plus links between resources, people/organizations, publications, models, workflows, software, activities, etc.


EarthCube
management of standards and identifiers
long term preservation
social networking
provenance, trust
research workflows
governance policies
and agreements
brokering services
compute and storage resources
collaborative code development
search over federated catalogs
synthetic curated datasets
vocabulary cross-walks
Cross-domain integration
Domain systems
Research sites
Applications
Standard Services
Vocabularies
Metadata catalogs
Data archives
Community data models
Harvesters/uploaders
Hydrology
Geochemistry
Atmosphere … Soils … Ecology …

Interoperability Readiness

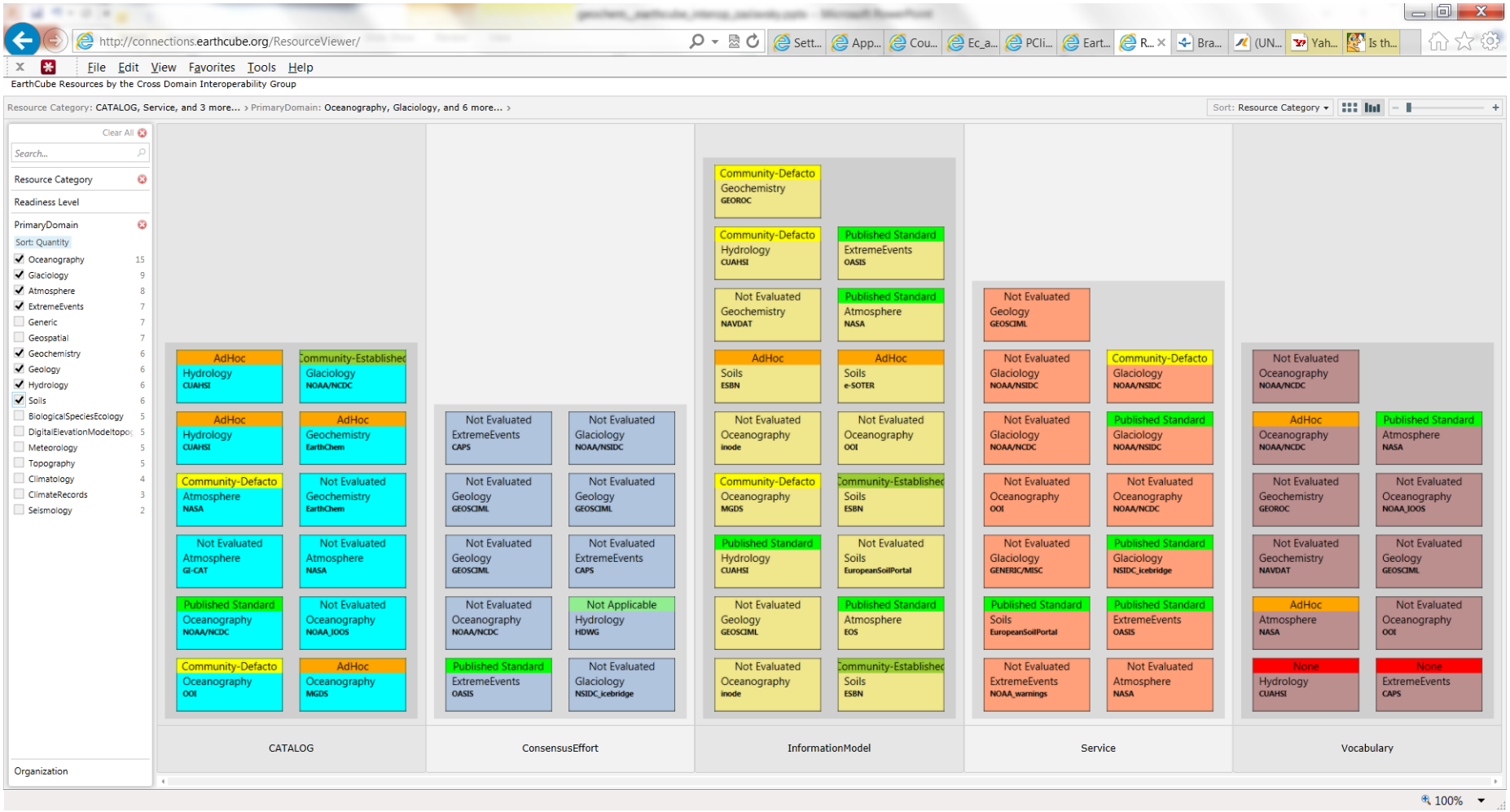
	Catalog Metadata
M1	Has a data listing
M2	Uses minimal metadata standard, such as Dublin Core
M3	Uses metadata standard, such as FGDC, or INSPIRE
	Catalog Search
S1	Search Interface
S2	Search API, not following a standard
S3	Complies with Opensearch API
S4	Complies with OGC CSW API
	Catalog Harvest
H1	Has a harvest API
H2	OAI API
H3	OGC CSW API

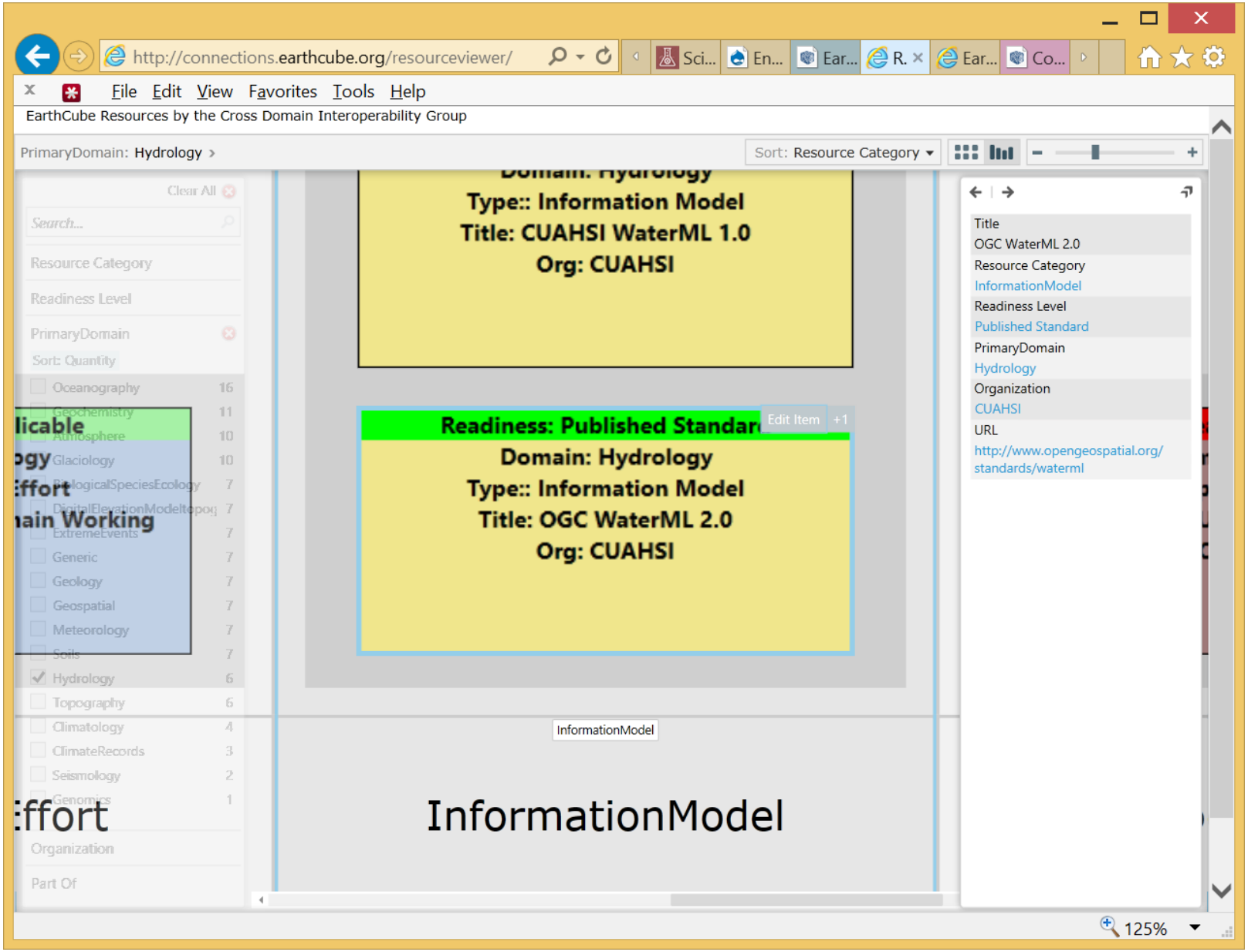
	Vocabulary – Control and Access
V1	Uses controlled terminology
V2	Community Managed Terminology
V3	SPARQL
	Vocabulary -- Representation
T1	Listing of terminology, such as web pages
T2	Uses ontology or SKOS

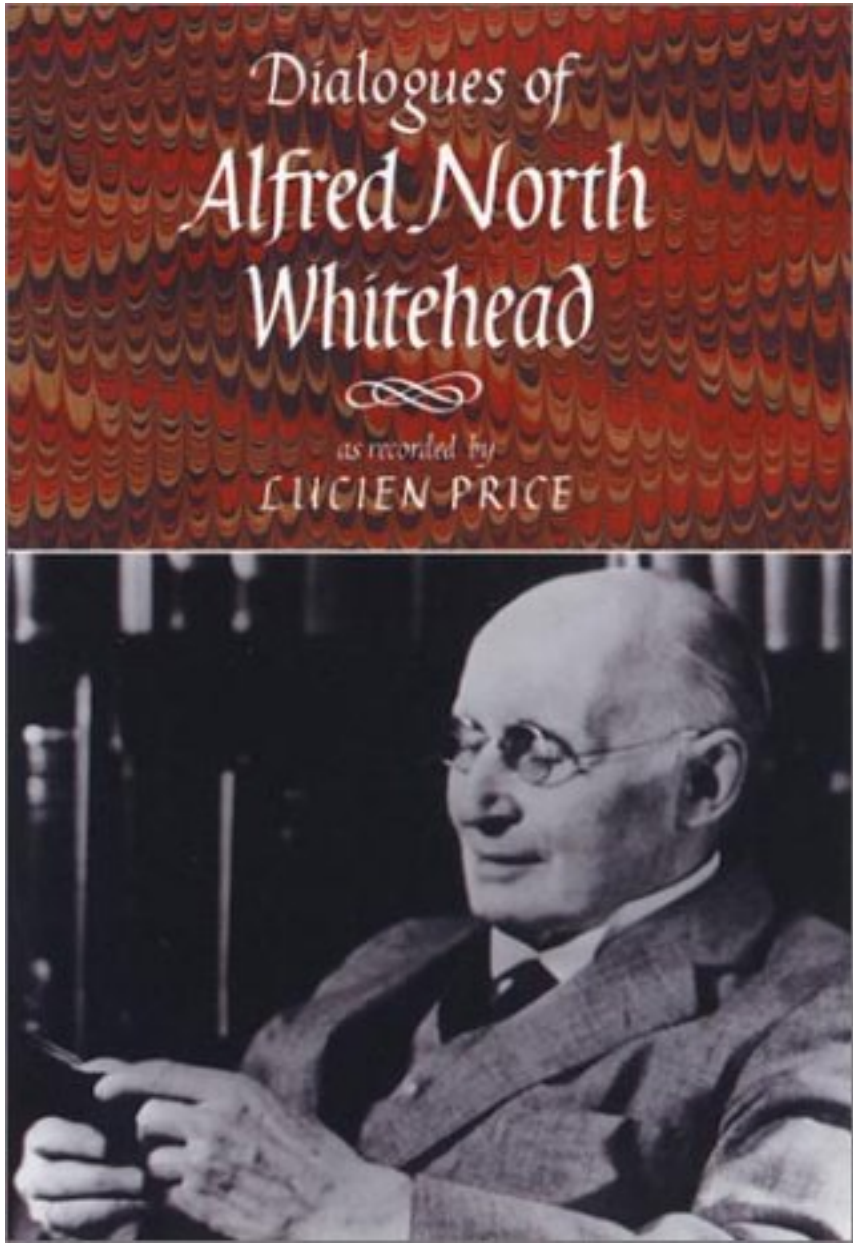
	Information Model Conceptual
C0	Unspecified
C1	Domain/Conceptual Model using UML
C2	Domain/Conceptual Model using UML based on OGC or ISO standards
	Information Model as XML
X1	XML Format. Schema may not be specified
X2	Xml Schema
	Information Model as SQL
S1	Provides an SQL Schema

	Data Access API
A1	Bulk download
A2	Static URL
A3	Web Service
	Data Query API
Q1	Simple query subset
Q2	Complex query
Q3	Processing Subset

Community curated inventory and readiness assessment




http://connections.earthcube.org/resourceviewer/
File Edit View Favorites Tools Help
EarthCube Resources by the Cross Domain Interoperability Group
PrimaryDomain: Hydrology
Sort: Resource Category
Type:: Information Model
Title: CUAHSI WaterML 1.0
Org: CUAHSI
Readiness: Published Standar
Edit Item
+1
Domain: Hydrology
Type:: Information Model
Title: OGC WaterML 2.0
Org: CUAHSI
Title
OGC WaterML 2.0
Resource Category
InformationModel
Readiness Level
Published Standard
PrimaryDomain
Hydrology
Organization
CUAHSI
URL
http://www.opengeospatial.org/standards/waterml
Clear All
Search...
Resource Category
Readiness Level
PrimaryDomain
Sort: Quantity
Oceanography 16
Geochemistry 11
Atmosphere 10
Glaciology 10
BiologicalSpeciesEcology 7
DigitalElevationModelTopog 7
ExtremeEvents 7
Generic 7
Geology 7
Geospatial 7
Meteorology 7
Soils 7
Hydrology 6
Topography 6
Climatology 4
ClimateRecords 3
Seismology 2
Genomics 1
Organization
Part Of
InformationModel
InformationModel
125%



"Civilization advances by extending the number of important operations which we can perform without thinking of them…"

Alfred North Whitehead. An Introduction to Mathematics (1911), ch. 5