WEATHER CLIMATE WATER
TEMPS CLIMAT EAU

Region VI Capacity Building 29 January 2024 (online) WHOS architecture design, insights and demonstration

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WMO OMM
World Meteorological Organization
Organisation météorologique mondiale

Agricultural metaphor on data sharing to WHOS

Where and what type of trees to plant?

How to gather their fruits?

How to prepare them for sharing and use?

How to send them to the market?

Market

End users

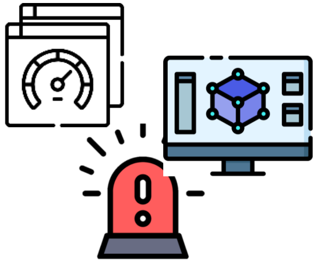
Network design and implementation

Data collection

Data and metadata preparation

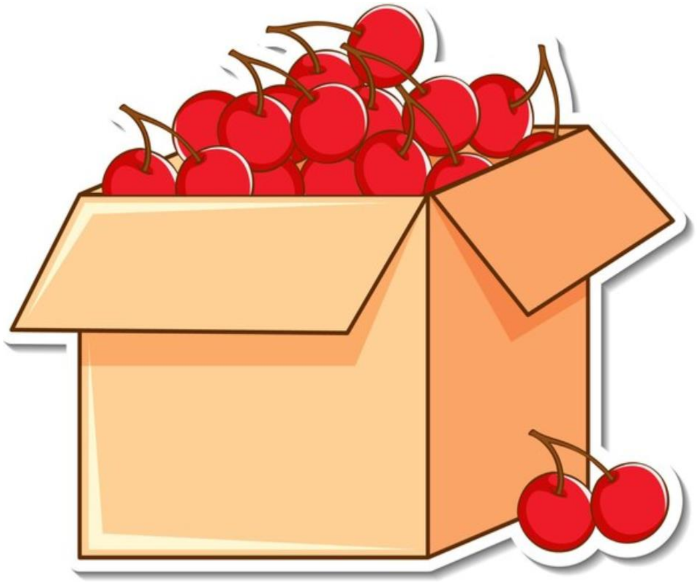
Web services

WHOS broker



End users

Workshop focus



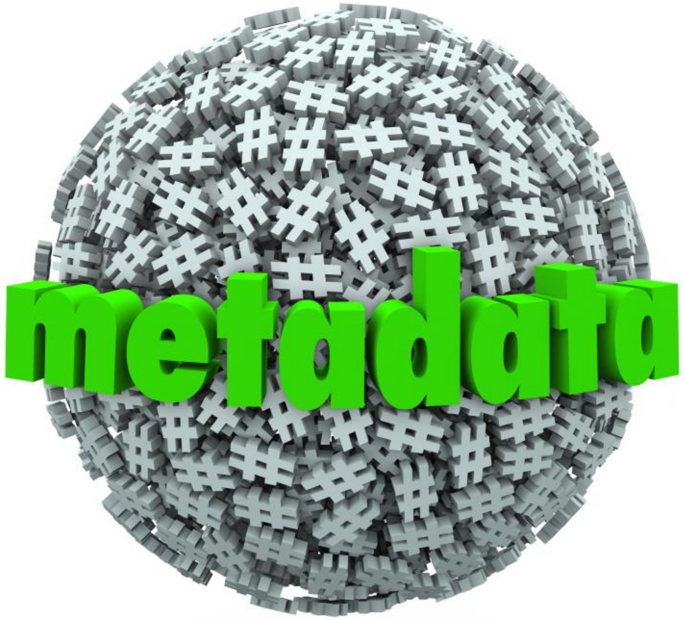
How to prepare them for sharing and use?

Data and metadata preparation

What is metadata and why?

Metadata is the data describing the data.

- Observations without metadata are of very limited use
- Necessary to provide users with confidence that the data are appropriate for their application
- Can be data depending on user needs and objectives



Metadata should be documented and treated with the same care as the data

The importance of metadata

Water level is 235 depth units!

Are you afraid there will be a flood?

You need more information to understand what the data mean!

Essential metadata can help:
(units of measurement)

- 235 (cm) = 2.35 meters
- Daily dam releases expose instrument to temporary water level rise
- The station is 30 km downstream and 50 meters lower in elevation

Metadata provides information necessary to use data correctly and responsibly

Metadata types

Discovery metadata allow users to discover data and answer the following questions:

What does the data set contain?

Where were the data collected?

Who is the data provider?

When are the observations taken?

Evaluation metadata enable users to understand better the data

Measurement units

Station operating status

Measurement/observing method

Diurnal base time

Use metadata allow end-users to access and use data

Data policies

Access service linkage

Access service protocol

Possible aggregation of data in hydrology

Data aggregation levels

- Single observation
- Time series
- Datasets
- Dataset series (collection)

Aggregation ↓

Possible aggregation of data in hydrology and associated metadata examples

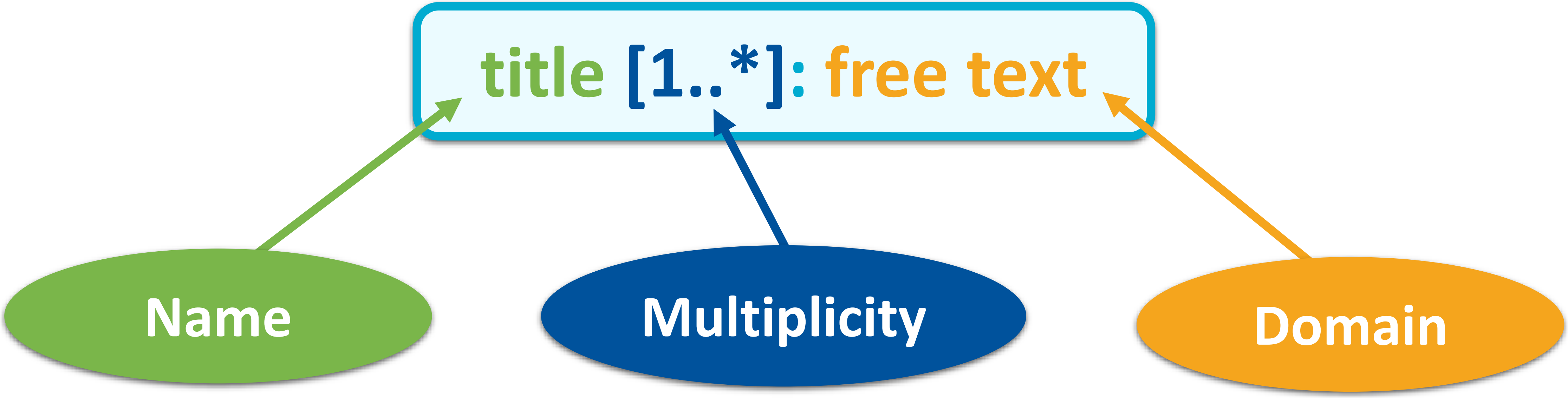
Data aggregation levels	Data examples	Possible metadata	Metadata examples
Single observation	Time ; Value pair 18 Jan 2023 00:00 ; -5.3	Quality flag	Valid
Time series	A time series of temperature observations at a site	Observed property	Temperature
Datasets	A set of time series from a single station	Responsible organization	ISRBC
Dataset series (collection)	Multiple datasets from a homogeneous network	Number of stations	9999

Examples of metadata elements of a dataset

Metadata elements	Name	Definition	Multiplicity	Domain	Example
	Title	Name by which the dataset is known	1 or more are required	Free text	**Title** = Precipitation time series from Blue Lake station
	Latitude	Latitude of the station in decimal degrees	1 is required	Decimal number	**Latitude** = 34.63
	…	…	…	…	

Standard data & metadata model specifications often provide definition tables like this one

Compact notation



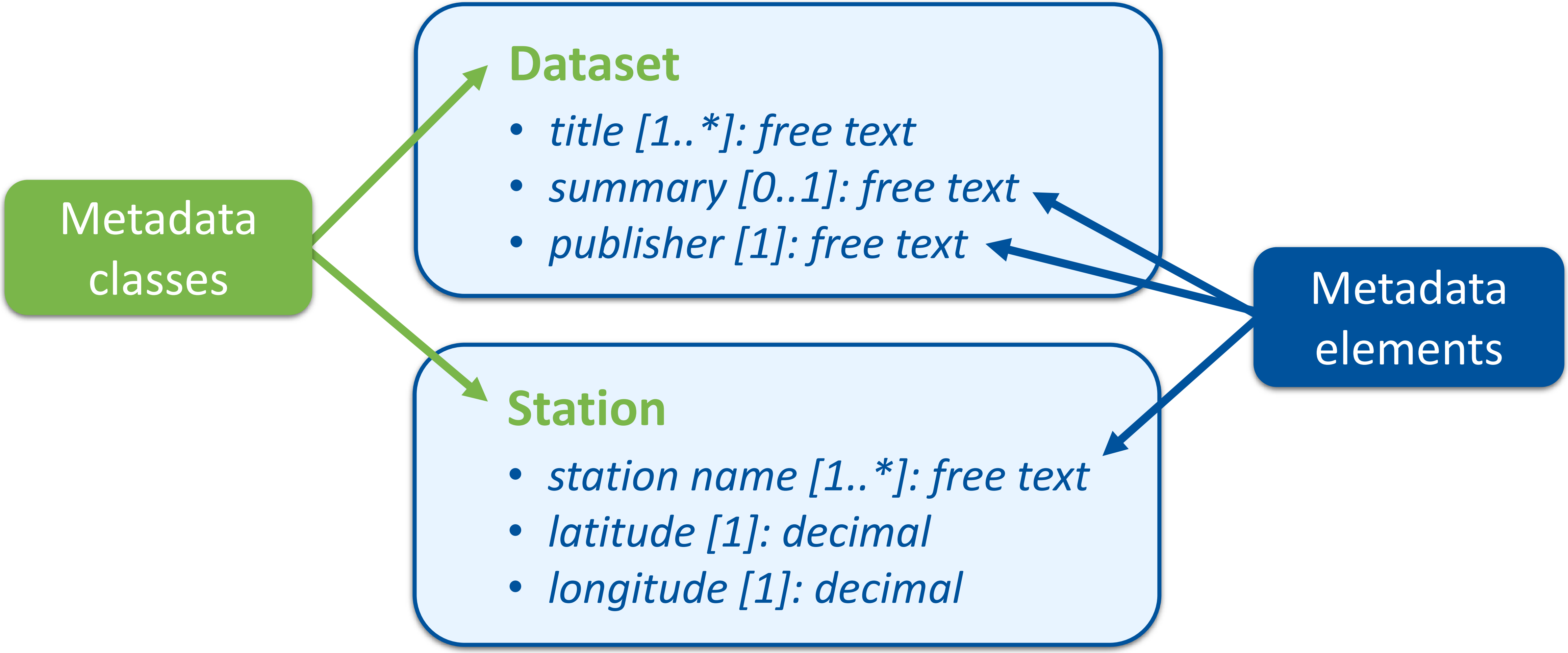
[1..*] - 1 or more occurrences are required

[0..1] - 0 or 1 occurrence is required

[1] - exactly 1 occurrence is required

Standard metadata model specifications often provide notations like this (UML based)

Metadata class: a set of related metadata elements



Standard data & metadata model specifications often provide notations like this (UML based)

Complex metadata elements

Dataset

- *station [1..*]: Station*
- *title [1]: free text*

elements that also serve as a metadata class

Station

- *name [1]: free text*
- *latitude [1]: decimal*
- *longitude [1]: decimal*

Example:

d: Dataset

- ***station = s1, s2***
- *title = A datasets from multiple stations*

s1: Station

- *name = Blue Lake*
- *latitude = 13.345*
- *longitude = 43.532*

s2: Station

- *name = Red Bridge*
- *latitude = 13.432*
- *longitude = 44.211*

Standard data & metadata model specifications often provide notations like this (UML based)

Metadata (and data) standards

- Usually metadata standards start as **community technical specifications**, schemas developed by a particular user community for specific needs. Examples:
  - **WaterML** in Hydrology
  - **Ecological Metadata Language** (EML) in Biodiversity
  - **NetCDF-CF** conventions for Climate
- They may start as well with the support of **dedicated organizations facilitating their discussion**, **drafting** and **publication** such as OGC
- Technical specs become **international standards** when their text is ratified by international standardization organizations (e.g. ISO, W3C)

Metadata and data standards

Abstract model standard

- to define allowed metadata classes and elements, their meanings, domains, multiplicity, etc.

Encoding standard

- to provide information on how to traduce the abstract model into machine-readable format

Example: **ISO 19115** defines a metadata model holding more than 400 elements for describing georeferenced datasets

Example: **ISO 19139** defines the XML schema used to encode ISO 19115 based metadata as XML documents

Different metadata standards for different aims

No ultimate metadata standard covering all domains exists (and probably will not exist)

❖ Generic metadata standards

✓ Support generic use cases across different domains (e.g. dataset discovery by means of basic discovery metadata elements) E.g. a user search matches keyword metadata elements from ISO 19115

❖ Topic- or community-specific

✓ Support specific community use cases (e.g. evaluating if a timeseries is fit for a specific hydrology model by means of evaluation metadata elements) Example: this timeseries has 1 hour as intended observing spacing (WaterML element), so is fit for my model

More specific

Dublin core — Describes: **multimedia, datasets, etc.**
Few elements

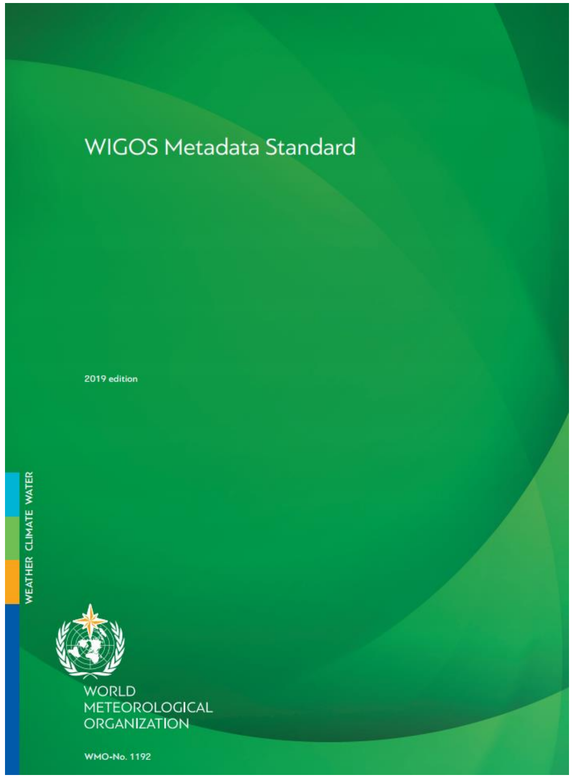
ISO 19115 — Describes: **geographic datasets**
400+ metadata elements

WaterML — Describes: **hydrological time series** (actually not only)
Less than 100 elements

Which to choose?
Fit for purpose is influenced by regional, national and organizational directives, laws, and requirements, organizational technical capacity & availability of IT experts, availability of implementing technologies

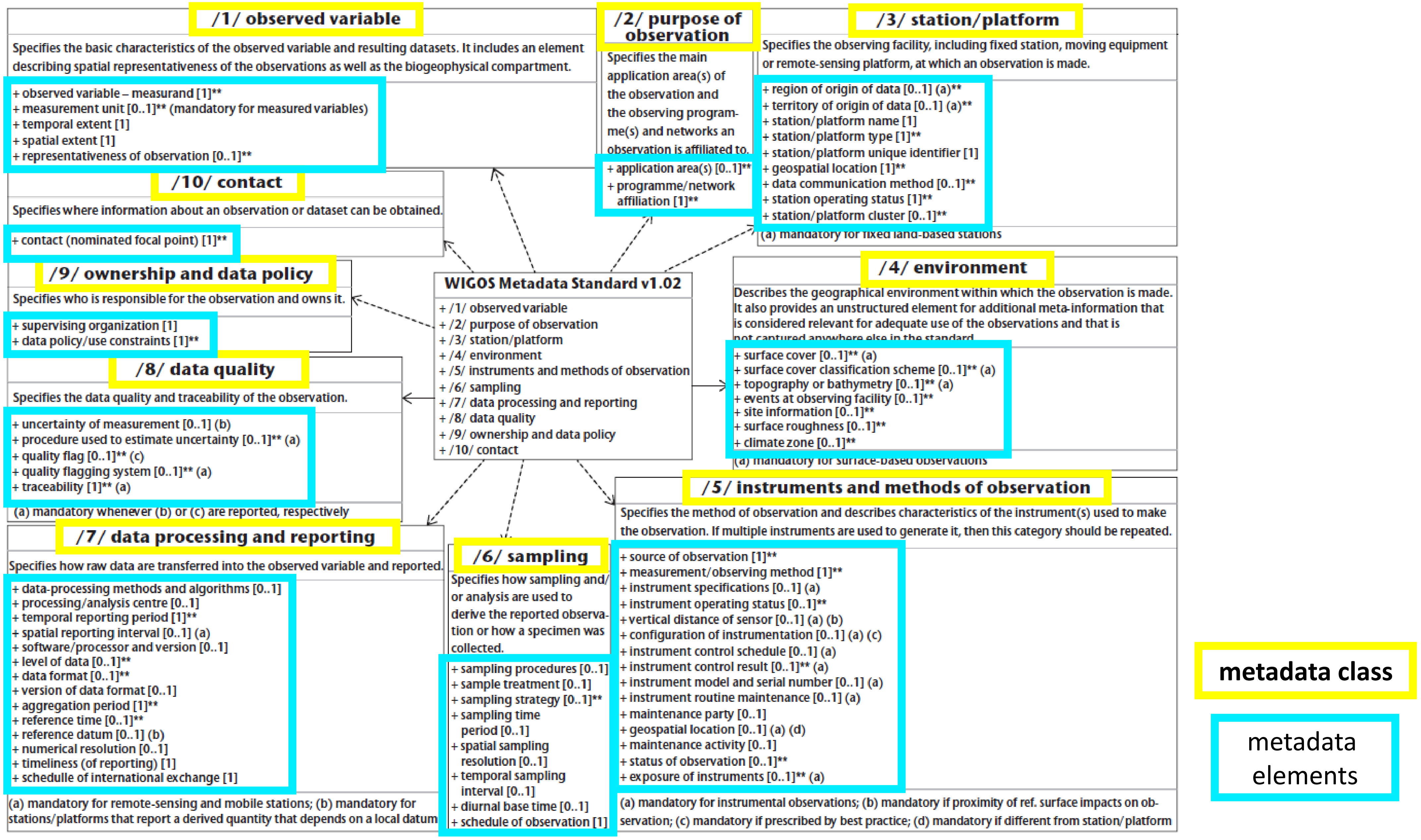
WMO Integrated Global Observing System (WIGOS) Metadata Standard

- Developed and published by the **WMO**
- Describes **observations**
- required for the effective utilization of observations from all **WIGOS** component (in particular OSCAR)
- enables to identify the conditions under which the observation was made, any aspect that may affect its use or understanding
- Information about the station including its history, the responsible parties, the instruments, the observed properties



WIGOS Metadata Categories

1. Observed variable	Specifies the basic characteristics of the observed variable and the resulting datasets
2. Purpose of observation	Specifies the main application area(s) of the observation and the observing programme(s) and networks the observation is affiliated to
3. Station/platform	Specifies the observing facility, including fixed station, moving equipment or remote-sensing platform, at which the observation is made
4. Environment	Describes the geographical environment within which the observation is made
5. Instruments and methods of observation	Specifies the method of observation and describes characteristics of the instrument(s) used to make the observation
6. Sampling	Specifies how sampling and/or analysis are used to derive the reported observation or how a specimen is collected
7. Data processing and reporting	Specifies how raw data are transferred into the observed variables and reported to the users
8. Data quality	Specifies the data quality and traceability of the observation
9. Ownership and data policy	Specifies who is responsible for the observation and owns it
10. Contact	Specifies where information about the observation or dataset can be obtained



/1/ observed variable
Specifies the basic characteristics of the observed variable and resulting datasets. It includes an element describing spatial representativeness of the observations as well as the biogeophysical compartment.
+ observed variable – measurand [1]**
+ measurement unit [0..1]** (mandatory for measured variables)
+ temporal extent [1]
+ spatial extent [1]
+ representativeness of observation [0..1]**
/2/ purpose of observation
Specifies the main application area(s) of the observation and the observing programme(s) and networks an observation is affiliated to.
+ application area(s) [0..1]**
+ programme/network affiliation [1]**
/3/ station/platform
Specifies the observing facility, including fixed station, moving equipment or remote-sensing platform, at which an observation is made.
+ region of origin of data [0..1] (a)**
+ territory of origin of data [0..1] (a)**
+ station/platform name [1]
+ station/platform type [1]**
+ station/platform unique identifier [1]
+ geospatial location [1]**
+ data communication method [0..1]**
+ station operating status [1]**
+ station/platform cluster [0..1]**
(a) mandatory for fixed land-based stations
/10/ contact
Specifies where information about an observation or dataset can be obtained.
+ contact (nominated focal point) [1]**
/9/ ownership and data policy
Specifies who is responsible for the observation and owns it.
+ supervising organization [1]
+ data policy/use constraints [1]**
WIGOS Metadata Standard v1.02
+ /1/ observed variable
+ /2/ purpose of observation
+ /3/ station/platform
+ /4/ environment
+ /5/ instruments and methods of observation
+ /6/ sampling
+ /7/ data processing and reporting
+ /8/ data quality
+ /9/ ownership and data policy
+ /10/ contact
/4/ environment
Describes the geographical environment within which the observation is made. It also provides an unstructured element for additional meta-information that is considered relevant for adequate use of the observations and that is not captured anywhere else in the standard.
+ surface cover [0..1]** (a)
+ surface cover classification scheme [0..1]** (a)
+ topography or bathymetry [0..1]** (a)
+ events at observing facility [0..1]**
+ site information [0..1]**
+ surface roughness [0..1]**
+ climate zone [0..1]**
(a) mandatory for surface-based observations
/8/ data quality
Specifies the data quality and traceability of the observation.
+ uncertainty of measurement [0..1] (b)
+ procedure used to estimate uncertainty [0..1]** (a)
+ quality flag [0..1]** (c)
+ quality flagging system [0..1]** (a)
+ traceability [1]** (a)
(a) mandatory whenever (b) or (c) are reported, respectively
/5/ instruments and methods of observation
Specifies the method of observation and describes characteristics of the instrument(s) used to make the observation. If multiple instruments are used to generate it, then this category should be repeated.
+ source of observation [1]**
+ measurement/observing method [1]**
+ instrument specifications [0..1] (a)
+ instrument operating status [0..1]**
+ vertical distance of sensor [0..1] (a) (b)
+ configuration of instrumentation [0..1] (a) (c)
+ instrument control schedule [0..1] (a)
+ instrument control result [0..1]** (a)
+ instrument model and serial number [0..1] (a)
+ instrument routine maintenance [0..1] (a)
+ maintenance party [0..1]
+ geospatial location [0..1] (a) (d)
+ maintenance activity [0..1]
+ status of observation [0..1]**
+ exposure of instruments [0..1]** (a)
(a) mandatory for instrumental observations; (b) mandatory if proximity of ref. surface impacts on observation; (c) mandatory if prescribed by best practice; (d) mandatory if different from station/platform
/7/ data processing and reporting
Specifies how raw data are transferred into the observed variable and reported.
+ data-processing methods and algorithms [0..1]
+ processing/analysis centre [0..1]
+ temporal reporting period [1]**
+ spatial reporting interval [0..1] (a)
+ software/processor and version [0..1]
+ level of data [0..1]**
+ data format [0..1]**
+ version of data format [0..1]
+ aggregation period [1]**
+ reference time [0..1]**
+ reference datum [0..1] (b)
+ numerical resolution [0..1]
+ timeliness (of reporting) [1]
+ schedulle of international exchange [1]
(a) mandatory for remote-sensing and mobile stations; (b) mandatory for stations/platforms that report a derived quantity that depends on a local datum
/6/ sampling
Specifies how sampling and/or analysis are used to derive the reported observation or how a specimen was collected.
+ sampling procedures [0..1]
+ sample treatment [0..1]
+ sampling strategy [0..1]**
+ sampling time period [0..1]
+ spatial sampling resolution [0..1]
+ temporal sampling interval [0..1]
+ diurnal base time [0..1]
+ schedule of observation [1]
metadata class
metadata elements

Data exchange formats in hydrology

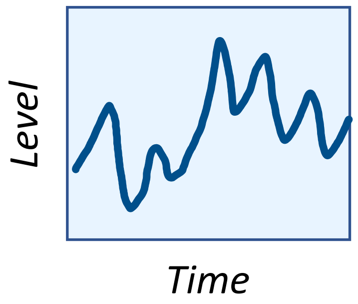
OGC® Making location count.

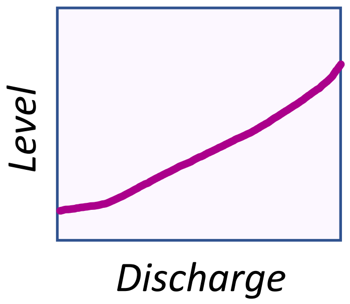
WaterML 2.0

WORLD METEOROLOGICAL ORGANIZATION

Implementation specifications

- Part 1 - Time Series
- Part 2 - Ratings, Gaugings and Sections
- Part 3 - Surface Hydrology Features
- Part 4 - GroundWaterML 2



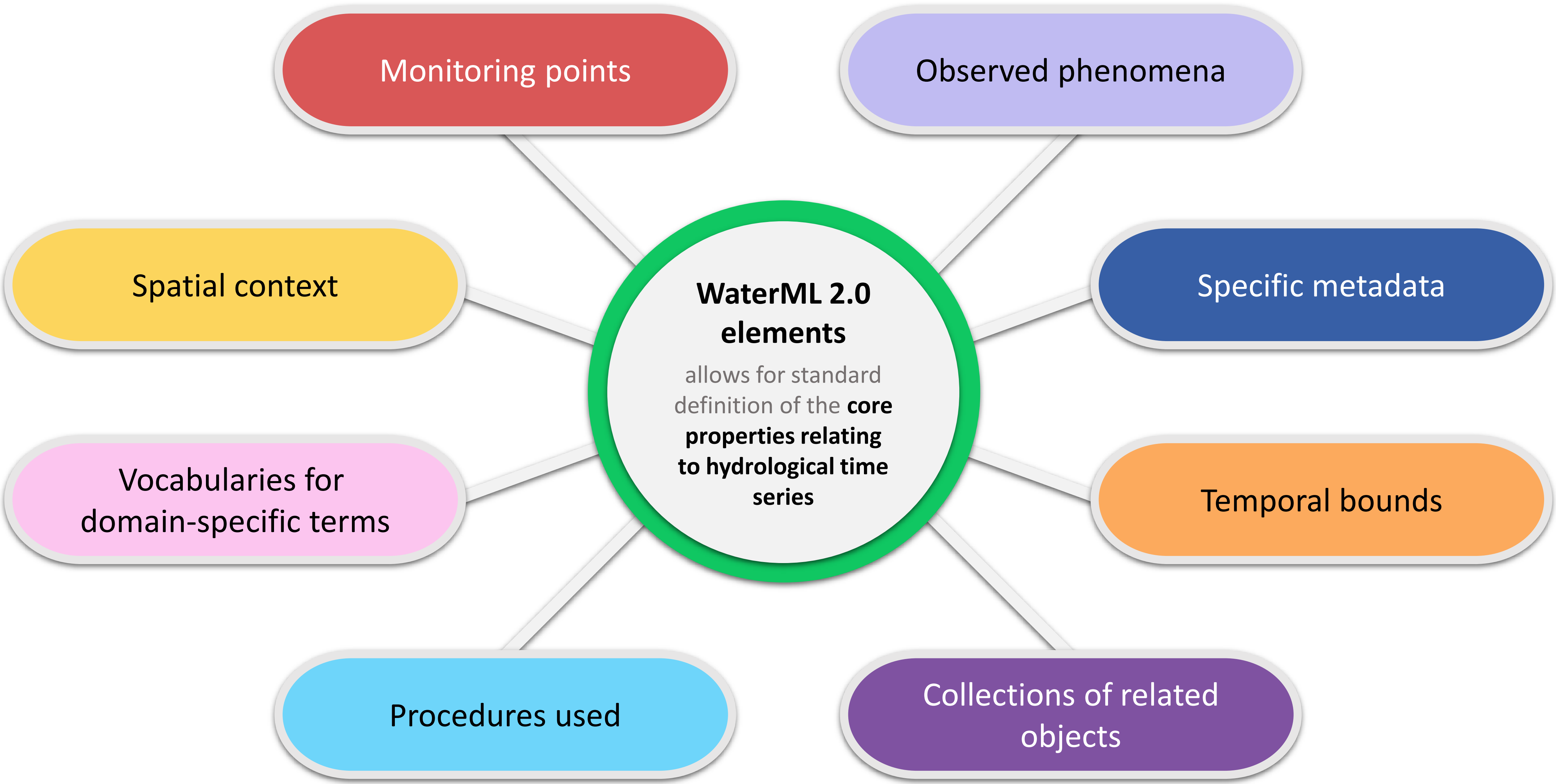


Best practices

- WaterML2-WQ (BP)

WaterML 2.0 enables data exchange between various information systems

https://www.ogc.org/standard/waterml/

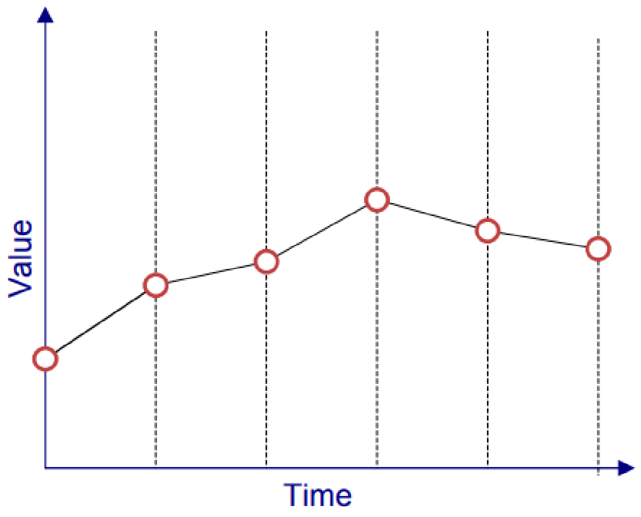

Monitoring points
Observed phenomena
Spatial context
Specific metadata
WaterML 2.0 elements
allows for standard definition of the core properties relating to hydrological time series
Vocabularies for domain-specific terms
Temporal bounds
Procedures used
Collections of related objects

Some of the essential WaterML 2.0 elements

			Example
observedProperty	Describes the phenomenon that is being observed	It is recommended to document with adequate concepts from controlled vocabularies/ontologies	<om:observedProperty xlink:href="http://codes.wmo.int/wmdr/ObservedVariableTerrestrial/171" xlink:title="**River discharge**">**River discharge**</om:observedProperty>
UnitOfMeasure	Describes the unit used for measurement	It is recommended to document with adequate concepts from controlled vocabularies/ontologies	<wml2:uom xlink:href="http://codes.wmo.int/common/unit/m3_s-1" xlink:title="**cubic metres per second**" code="**m3/s**"/>
interpolationType	Describes the procedure used in making the estimate that the value represents	It is recommended to document with adequate concepts from OGC controlled vocabulary	<wml2:interpolationType xlink:href="http://www.opengis.net/def/waterml/2.0/interpolationType/Continuous" xlink:title="**Continuous**"/>

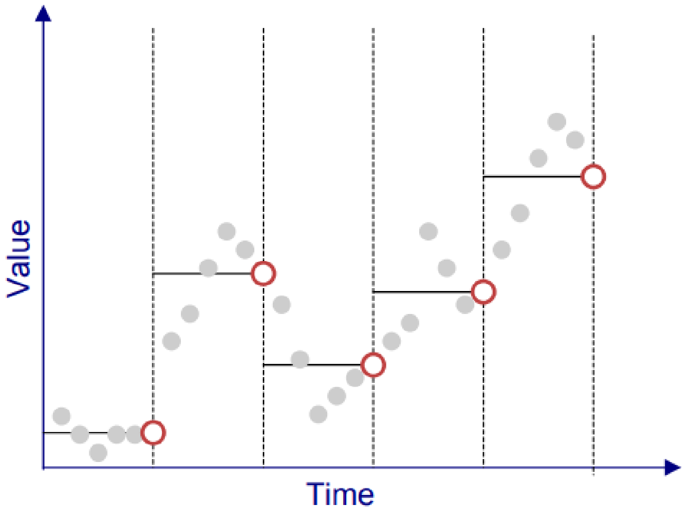
Examples of the interpolation types

Continuous/ Instantaneous



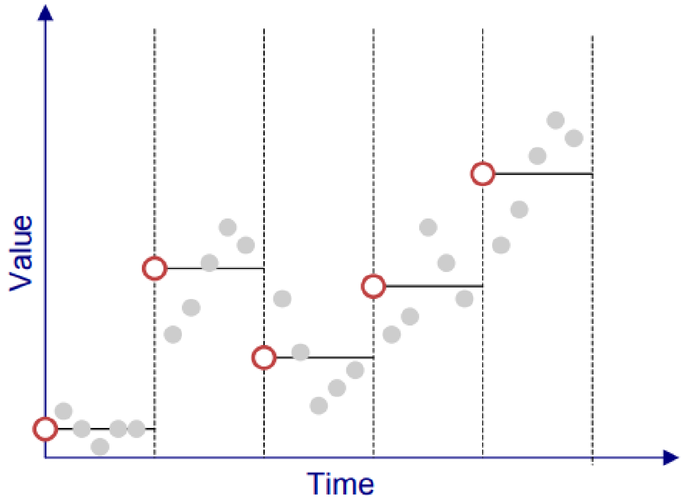
e.g. instantaneous water level

Average in preceding interval



e.g. average air temperature in the last hour

Average in succeeding interval



e.g. average air temperature in the next hour

Overview of important WaterML metadata elements in the WHOS experience

Observation related elements

- **Observed property** (e.g. temperature, discharge (http://codes.wmo.int/wmdr/ObservedVariableTerrestrial/171), Amount of precipitation (http://codes.wmo.int/wmdr/ObservedVariableAtmosphere/210), etc.)
- **Phenomenon time**
  - **Begin time** (e.g. 2000-01-01T00:00:00Z)
  - **End time** (e.g. 2000-02-01T00:00:00Z)
- Result time (e.g. 2000-02-01T00:00:00Z) (e.g. including data elaboration)
- Valid time (useful especially for forecasts)
- <u>Result quality</u> (overall quality, as expressed by ISO 19115, e.g. conformity, or quantity result)
- <u>Resource identifier</u>
- **Contact point organization**
  - **Organization name**
  - **Organization email (mandated by INSPIRE)**
  - **Role (example given, originator, publisher, …)**
  - **Organization address, including country**
- **dateStamp (of data)**

- <u>topic category</u>
- <u>keywords</u>
- <u>limitations on public access</u> (Core/recommended)
- <u>conditions for access and use</u>
- <u>intended observation spacing</u> (e.g. PT5M)
- sampled medium (e.g. water, ground water, surface water, sediment, pore water, pore air, soil, soil air, soil water, atmosphere, tissue, ground snow, unknown)
- maximum gap
- Any other metadata element from ISO 19115 (e.g. <u>title</u>, <u>abstract</u>)

Metadata related elements

- Datestamp (of metadata)
- Metadata identifier
- <u>Contact point organization</u>

- **Strongly recommended**
- <u>Recommended</u>
- Optional

Overview of important WaterML metadata elements in the WHOS experience

Feature of interest (FOI) & monitoring points

- FOI Type (e.g. sampling point, sampling curve, sampling surface)
- **Name**, alternate names;
- Connection to a group of measuring sampling points;
- Identifiers (individual organizations may have separate identifiers);
- <u>Responsible organization (e.g., originator)</u>;
- Lineage
- Classification of the sampling point;
- Operator;
- Time zone in which the sampling point is located;
- **Spatial location**
  - **Latitude**
  - **Longitude**
  - <u>Altitude</u>
- Links to hydrological hierarchies such as catchments, stream networks, regions etc.
- Comments containing extra descriptive information regarding the sampling point.
- Positional accuracy
- Time zone
- Daylight savings time zone (e.g. +10:00 GMT)
- Related party
- Description reference
- Monitoring type (WMO categories)
- Vertical datum

- **Strongly recommended**
- <u>Recommended</u>
- Optional

Overview of important WaterML metadata elements in the WHOS experience

Cumulative time series metadata elements

- Accumulation Anchor Time (e.g., at 09:00)
- Accumulation Interval Length (e.g. 24 hours)

Observation process (e.g. instrument) metadata elements

- Process type (e.g. simulation, manual method, sensor, algorithm, unknown)
- Process reference
- Vertical datum
- Parameter
- Operator
- Comment
- input

- **Strongly recommended**
- <u>Recommended</u>
- Optional

Overview of important WaterML metadata elements in the WHOS experience

Point metadata elements

- Censored reason
- Accuracy (e.g. 0.1 http://codes.wmo.int/common/unit/m3_s-1)
- <u>Aggregation duration</u> (e.g. P1D)
- <u>Uom</u> (e.g. http://codes.wmo.int/common/unit/m3_s-1)
- <u>Interpolation type</u> (e.g. Continuous, 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, http://defs.opengis.net/vocprez/object?uri=http%3A//www.opengis.net/def/waterml/2.0/interpolationType/Continuous, …)
- quality (es. good, suspect, estimate, poor, unchecked, missing)
- Point specific comment

- **Strongly recommended**
- <u>Recommended</u>
- Optional

Metadata modelling: situation in the world

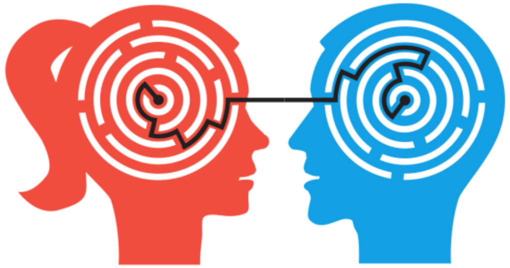
- often not handled with data-sharing in mind
- prioritizes internal needs over the needs of broader user communities
- there is no single correct way of representing information
- same information is often represented in the variety of ways
- use of free text values generates heterogeneity and ambiguities

Semantics

Refers to the meaning and interpretation of words, signs, and sentence structure

Different data providers may use:

- different terms for the same parameters: precipitation, rainfall
- different languages for same terms: precipitation, pioggia
- the same language and the same term, but the meaning may still be different: [stream] level, [snow] level



Controlled vocabularies → **Improving semantics** ← **Ontologies**

Make metadata and data more discoverable, accessible, interoperable, and reusable

Free text terms e.g. rainfall, rain, precipitation, pioggia, chuva → are replaced by → **Controlled term** from the vocabulary (or ontology) e.g. Precipitation amount

Controlled vocabularies

*Refer to a **carefully selected list of terms** by a specific organization/community, which are used to document specific metadata elements*

Data provider "X"

can document its metadata elements:

e.g., Observed variable

e.g., Measurement unit

Community "A"

Observed variable vocabulary:

- Level, stream
- Discharge, stream
- ...

Measurement unit vocabulary:

- m
- m^3/s
- ...

Community "B"

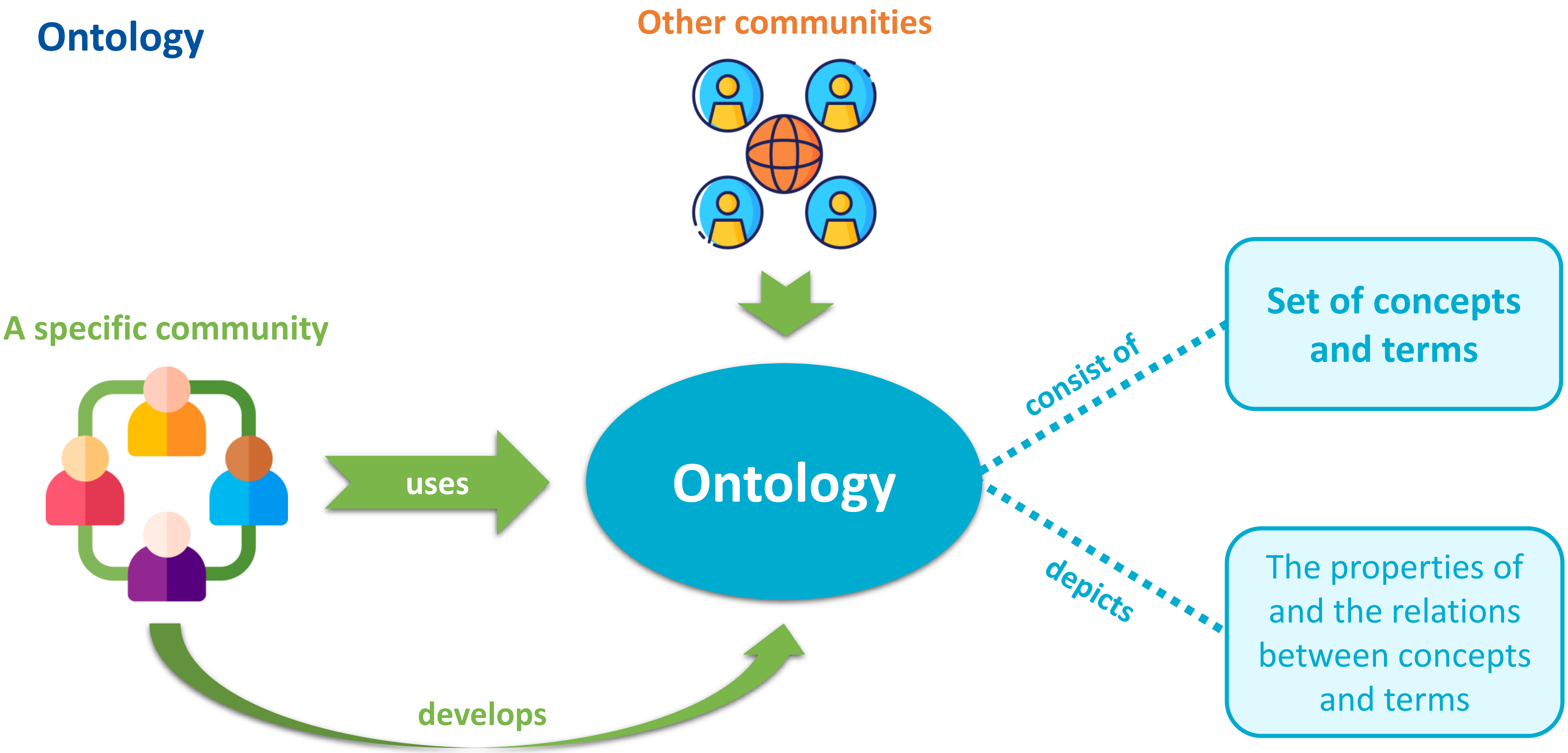
Observed variable vocabulary:

- Stage
- Streamflow
- ...

Measurement unit vocabulary:

- m
- m^3/s
- ...

Ontology


Other communities
A specific community
uses
Ontology
develops
consist of
depicts
Set of concepts and terms
The properties of and the relations between concepts and terms

WHOS Hydro ontology

CUAHSI universities allied for water research | WMO Codes Registry | WHOS

- **Concepts:** from the CUAHSI Ontology, WMO Codes registry, WHOS data provider community
  - **preferred labels** (from the CUAHSI ontology)
  - **alternative labels** (synonyms, including in different languages)

- **Relations between concepts** (from the CUAHSI ontology)
  - **Narrower** (Stream level is anarrower concept of level)
  - **Broader** (Level is a broader concept of stream level)

To enable machine to machine interaction, the hydro-ontology is available as a SPARQL endpoint

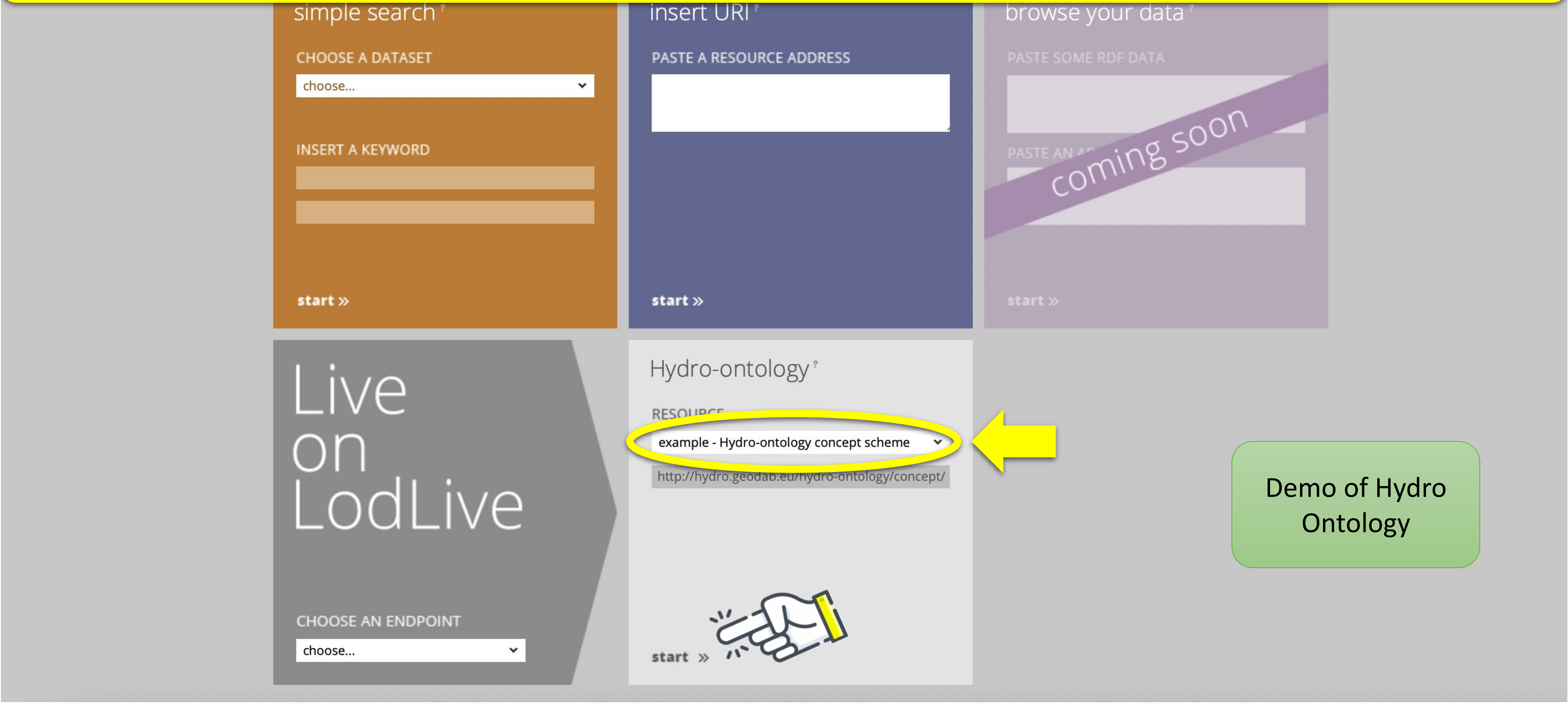
Controlled vocabularies and ontologies at different levels

Organizational level	Community level	International level

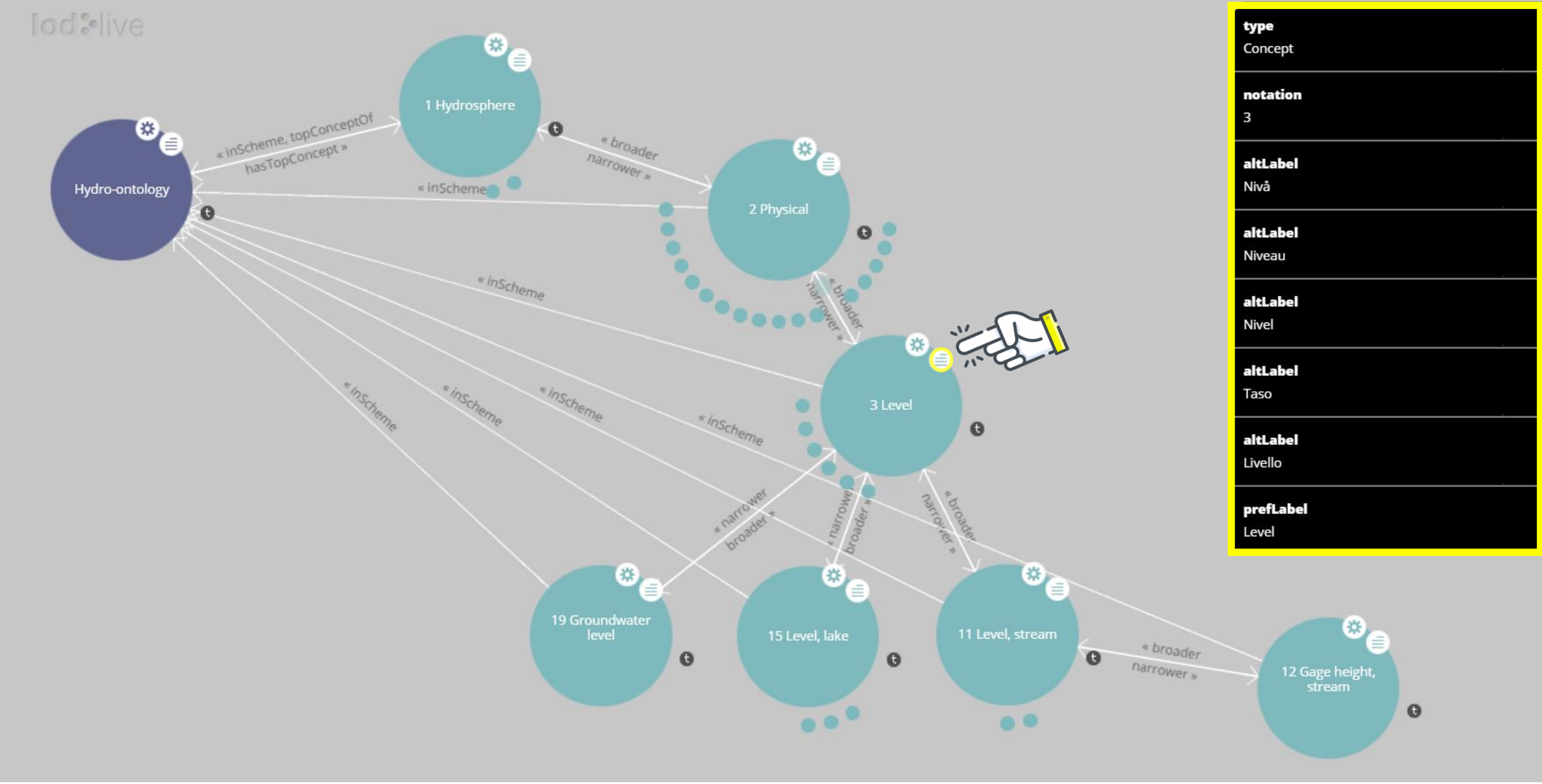
Agreed-upon and practiced controlled vocabularies and ontologies by:

a specific organization	a specific community	internationally
e.g., custom table in a database	e.g., CUAHSI Hydrologic Concept ontology	e.g., WMO and ISO code list catalogs
	Demo of CUAHSI ontology	Demo of WMO Codes

http://hydro.geodab.eu:80/ontology-browser/hydro-ontology.html



Demo of Hydro Ontology



lod live
Hydro-ontology
1 Hydrosphere
2 Physical
3 Level
19 Groundwater level
15 Level, lake
11 Level, stream
12 Gage height, stream
« inScheme, topConceptOf
hasTopConcept »
« inScheme
« broader
narrower »
type
Concept
notation
3
altLabel
Nivå
altLabel
Niveau
altLabel
Nivel
altLabel
Taso
altLabel
Livello
prefLabel
Level

Metadata codelists

Observed properties → WMO codes https://codes.wmo.int/ ; WHOS Hydro ontology

Units of measurements → WMO codes https://codes.wmo.int/

Organizations → NVS vocabs https://vocab.nerc.ac.uk/collection/

Projects → NVS vocabs

How to send them to the market?

Web services

Publishing web services

Analysis and retrieval → **Publishing web services** → Dissemination

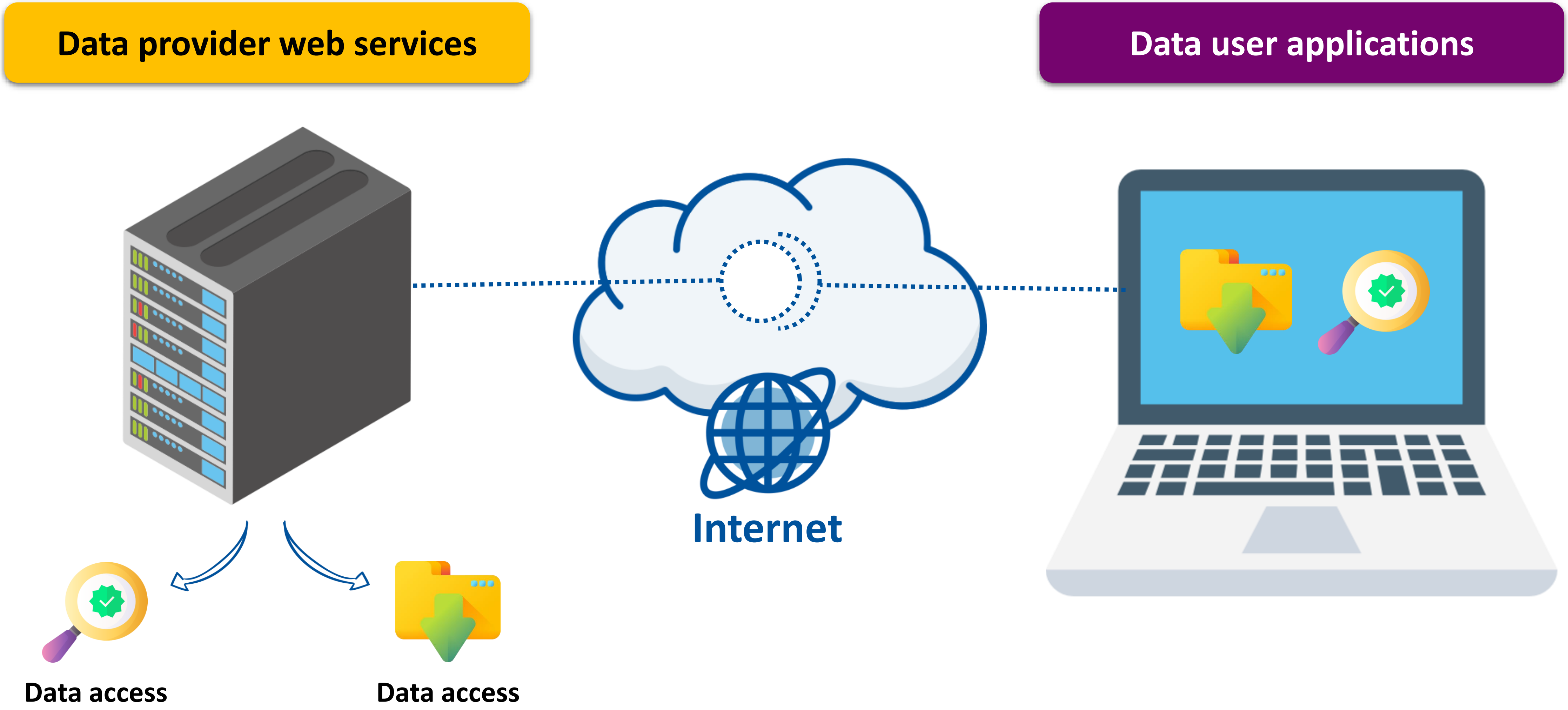
Discover data

search and find data of interest

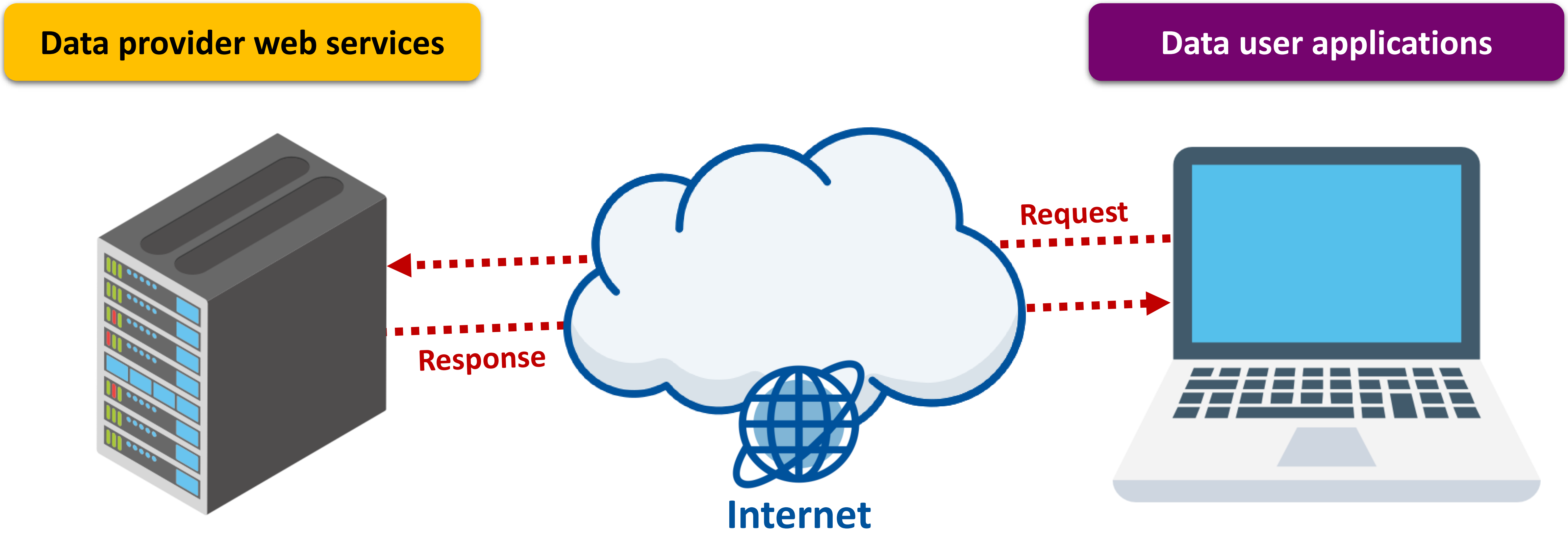
Access data

download the discovered data

Publishing web services



Interoperability



Two components can interoperate if both use a common communication protocols, data and metadata model

Service Oriented Architecture (SOA) and Resource Oriented Architecture (ROA)

SOA:
emphasis on giving/receiving a service (e.g., discovery, access)

Entry points are the service operations. They apply their functions by means of a set of parameters. Example:

- Get service capabilities
- Get records
  - Query constraints
- Get record by id
  - id

Example: OGC Web service specifications
- OGC Web Map Service (WMS)
- OGC Catalogue Service for the Web (CSW)
- …

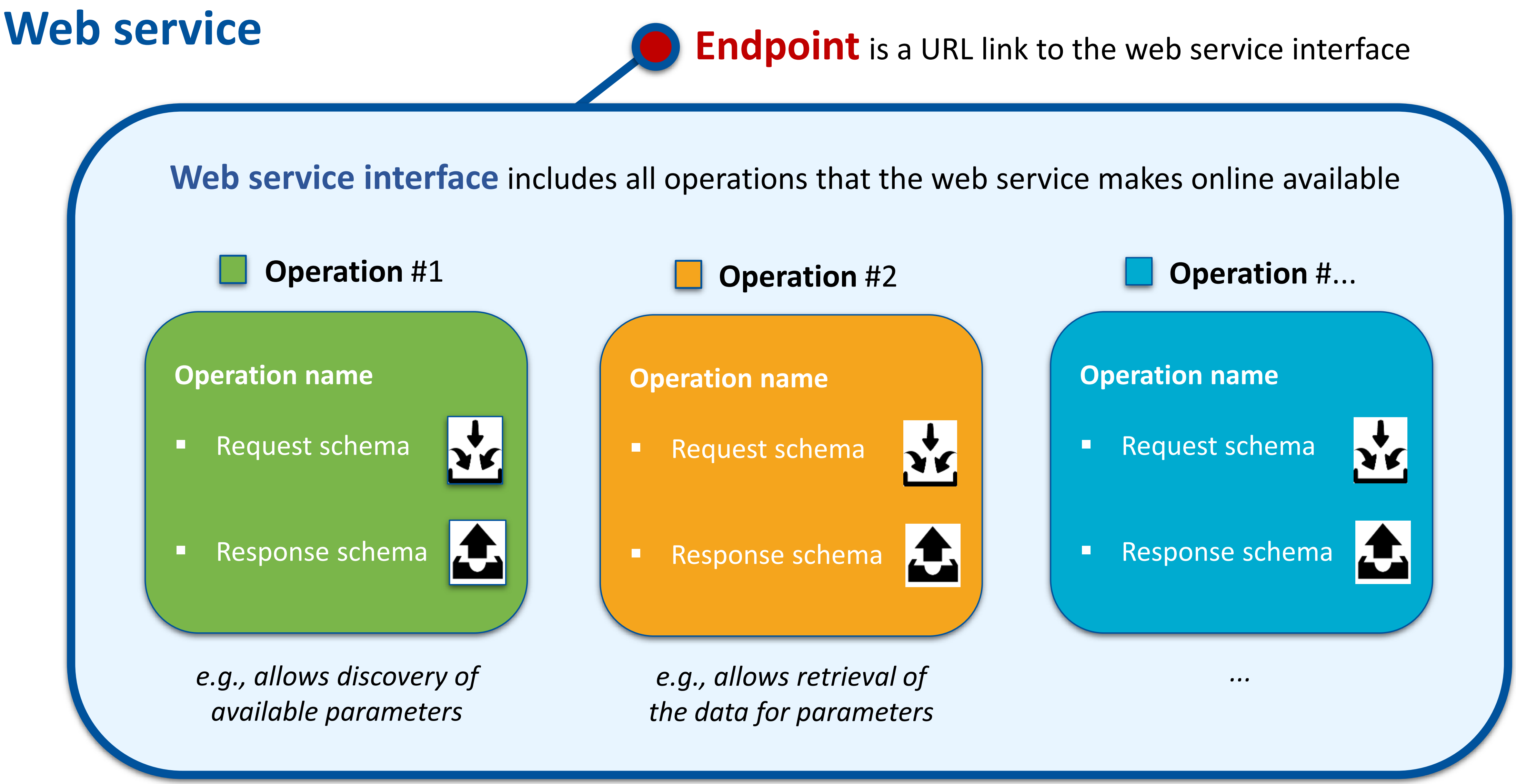
ROA:
emphasis on resource (e.g., metadata, data, station)

Entry points are the resources, they usually are operated by means of few HTTP operations. Example:

- Station
  - GET, DELETE, POST
- Time series
  - GET, DELETE, POST
- Data
  - GET, DELETE, POST

Example: OGC API specifications
- OGC API Record
- OGC SensorThings
- …

Service/API endpoint URL


Web service
Endpoint is a URL link to the web service interface
Web service interface includes all operations that the web service makes online available
Operation #1
Operation name
Request schema
Response schema
e.g., allows discovery of available parameters
Operation #2
Operation name
Request schema
Response schema
e.g., allows retrieval of the data for parameters
Operation #...
Operation name
Request schema
Response schema
...

Web service functionalities

Obtain
metadata

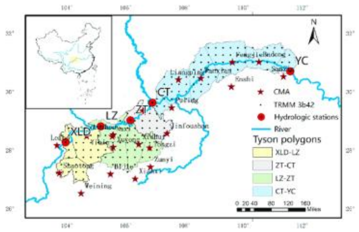
Discovery

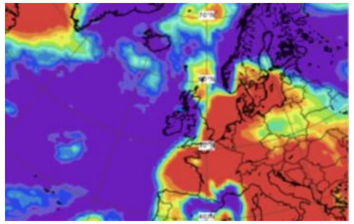
- **Catalogue service**: search metadata by constraints
- **Inventory service**: browse metadata repository

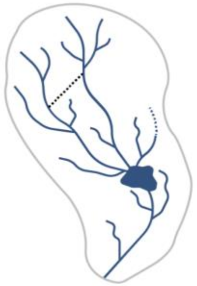
Obtain
data

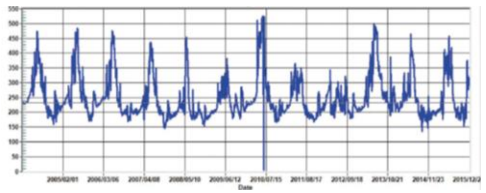
Access

- **Feature access**: vector data
- **Map access**: map images
- **Coverage access**: raster data
- **Sensor access**: time series

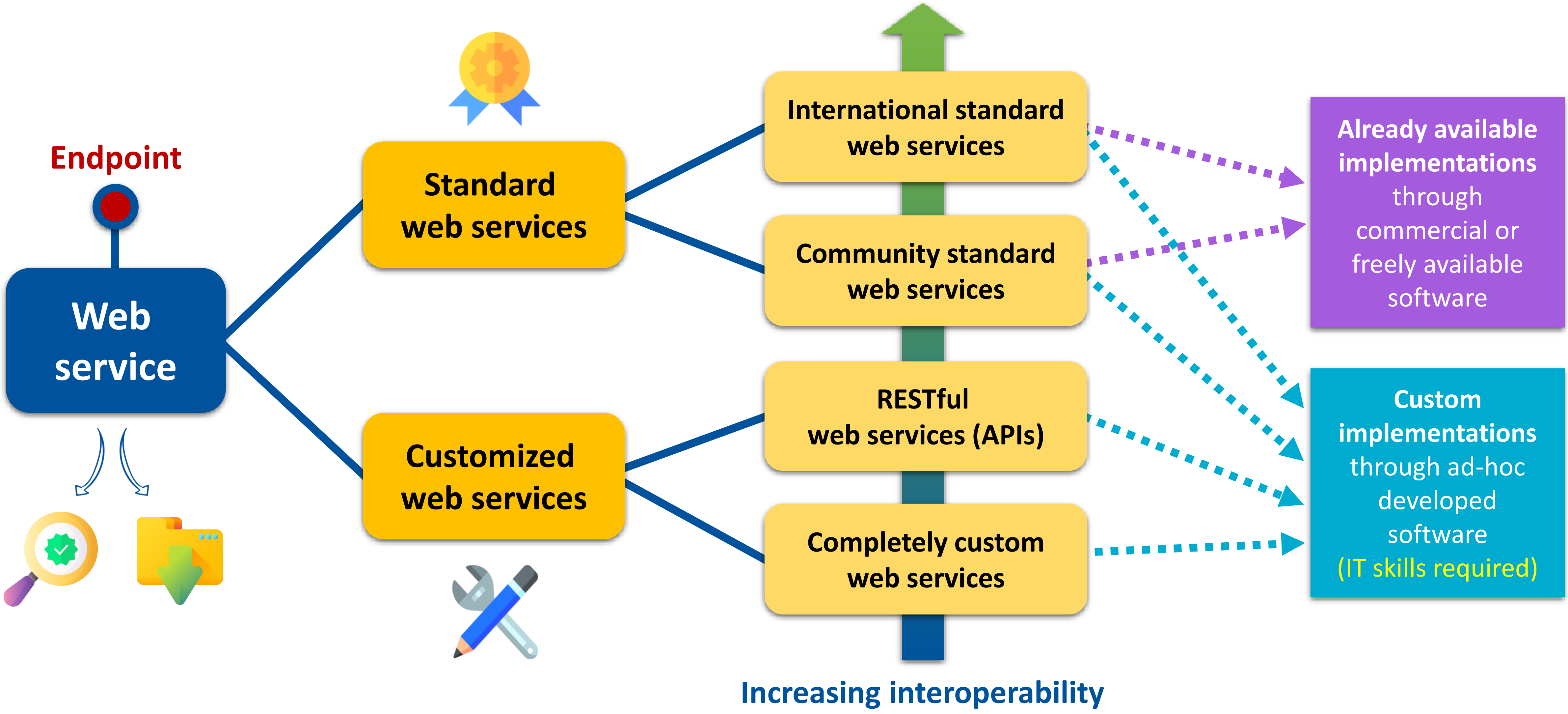








Standards and technologies for implementing a web service



Standard vs customized web services

Standard web services

- ✓ Availability of free and/or commercial tools already implementing their technical specifications
- ✓ Improved interoperability with users' tools and applications
- ✓ Ease of data and metadata interpretation

vs

Customized web services

- ✓ More flexibility for implementation in the context of organizational needs
- ✓ Rapid developments
- ✓ Possibility of custom extensions of tools

Customized web services

Completely custom web services

Custom requests/responses and a communication protocol

Examples of technologies supporting the implementation: SOAP, WSDL, Apache Axis, JAX-WS

Metadata / data models: standard based (e.g., ISO, OGC) or completely custom (e.g., XML based)

RESTful web services (APIs)

RESTful approach, Resource oriented, HTTP methods

Examples of technologies supporting the implementation: OData, OpenAPI/Swagger

Metadata / data models: standard based (e.g., ISO, OGC) or completely custom (e.g., JSON based)

Customized web services

- ✓ Make publicly available technical specifications of the published web services
- ✓ Keep performance in mind while designing web services operations
    - e.g., document temporal extent (start date/end date) of available data
- ✓ Ease accessibility of data
    - e.g., provide data subset functionality with customizable temporal extent as a parameter

Standard web services

Community standard web services

CUAHSI WaterOneFlow, THREDDS catalog service,...

Metadata / data models: CUAHSI WaterML 1.1, KISTERS ZRXP, USGS RDB, HDF, ...

International standard web services

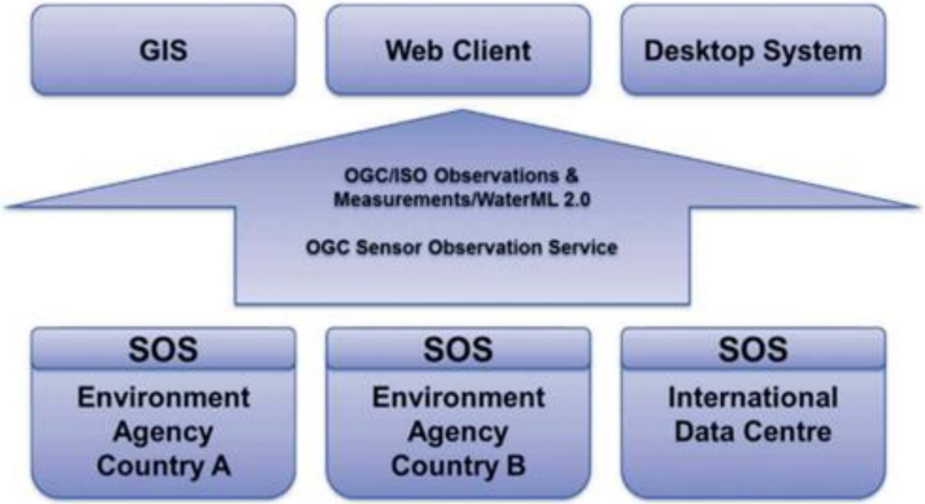
OGC services (e.g. CSW, SOS, WCS, WFS, WMS, ...), **FTP**, **OpenSearch** (de-facto standard), ...

Metadata / data models: ISO, OGC GML, OGC WaterML 2.0, OGC NetCDF, WIGOS ...

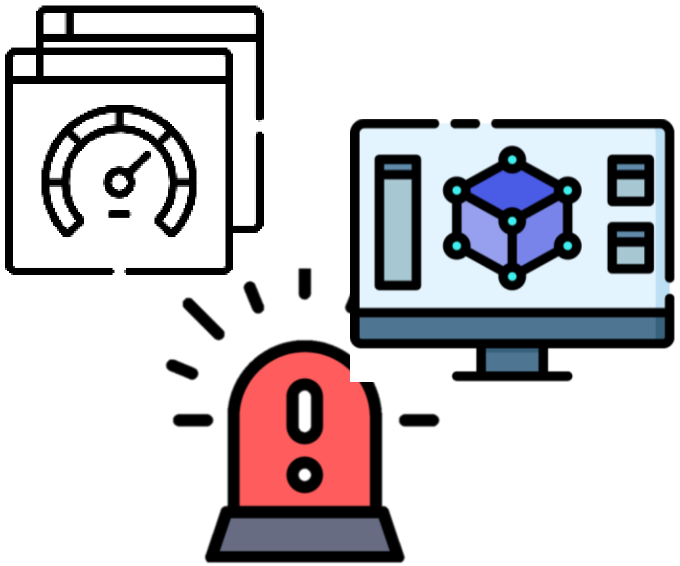
Example of international standard web service:
Sensor Observation Service (SOS)

SOS standard defines:

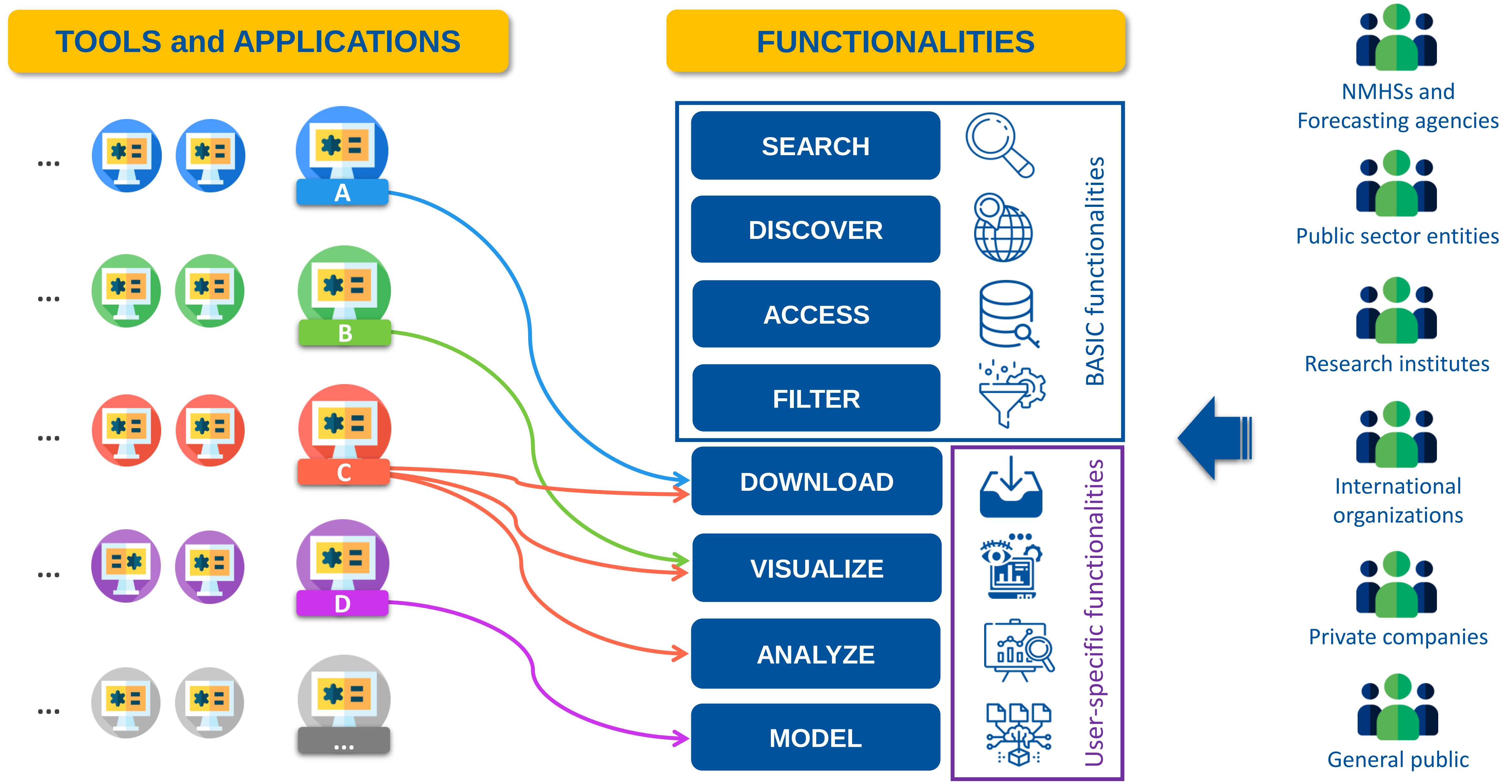
- a Web service interface which allows querying observations, sensor metadata, as well as representations of observed features
- means to register new sensors and to remove existing ones
- operations to insert new sensor observations



End users

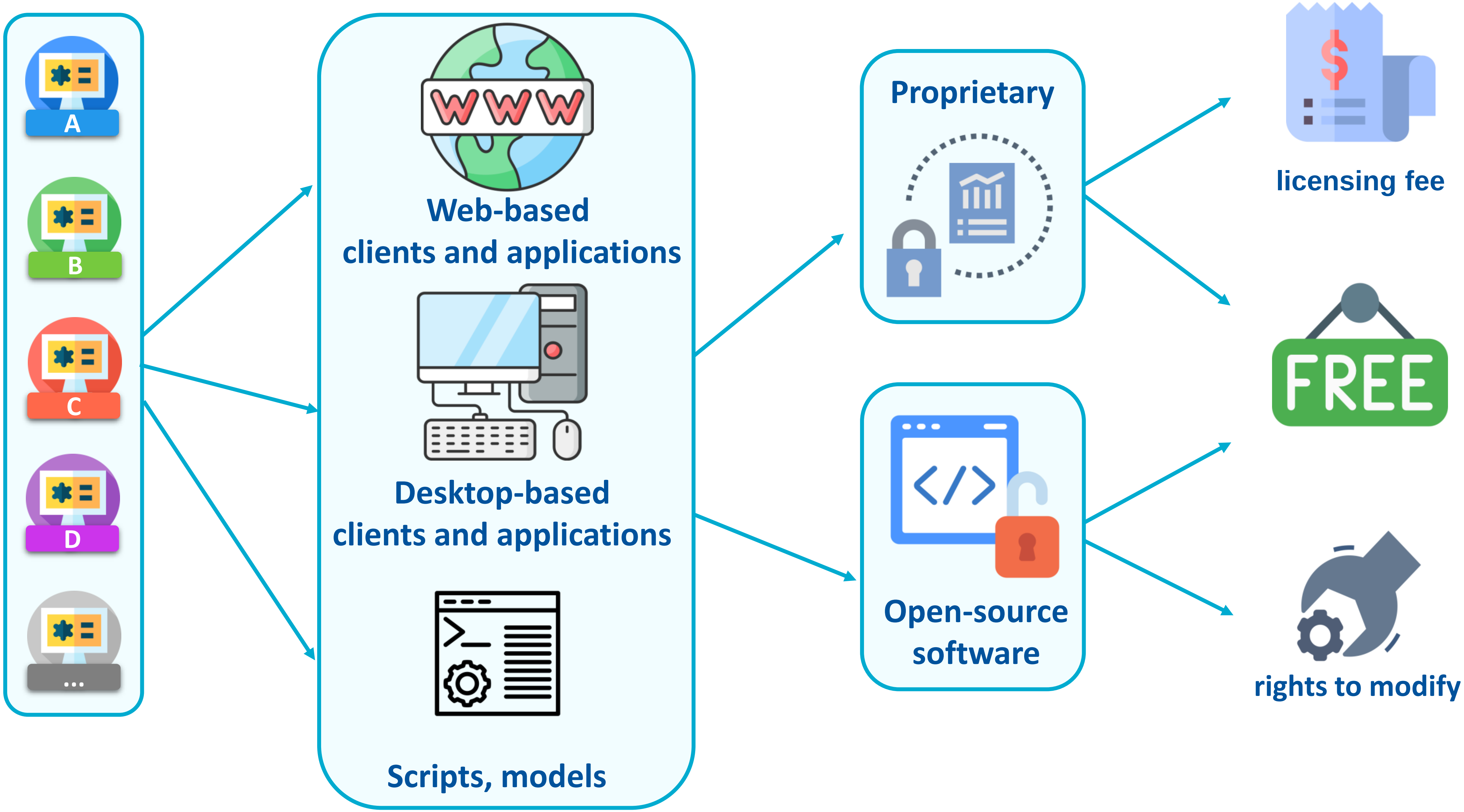


End users



TOOLS and APPLICATIONS
FUNCTIONALITIES
...
A
...
B
...
C
...
D
...
...
SEARCH
DISCOVER
ACCESS
FILTER
BASIC functionalities
DOWNLOAD
VISUALIZE
ANALYZE
MODEL
User-specific functionalities
NMHSs and Forecasting agencies
Public sector entities
Research institutes
International organizations
Private companies
General public

Web- and desktop-based tools and application



Web-based Tools and Applications

can be accessed and used on common web browsers

Strengths:

- ✓ Possible access from any location and on any device
- ✓ Ease of maintaining and updating
- ✓ Fast advancements in technologies
- ✓ Rapid data updates

Weaknesses:

- ✓ Potentially exposed to more data security risks (data is on the cloud)
- ✓ Might have lower performance in comparison to desktop applications

Desktop-based Tools and Applications

run stand-alone on a computer

Strengths:

- ✓ Do not depend on Internet connection (offline processing)
- ✓ Can be faster and more responsive than web applications
- ✓ Less exposure to potential security risks (data in the organization)

Weaknesses:

- ✓ Need to install them on each computer
- ✓ More IT skills are needed for maintenance and updates
- ✓ Might run only on the specific operating system (e.g., Windows, MacOS)
- ✓ Might not update new data as easily as web-based systems

Scripts, API clients, models

run stand-alone on a computer

Strengths:

- ✓ Fully customizable processing

Weaknesses:

- ✓ Advanced IT skills are needed

Different functionalities – different tool types – different standards

Functionalities

- Data consultation
- Data visualization
- Data analysis
- Data processing
- Data modelling
- ...

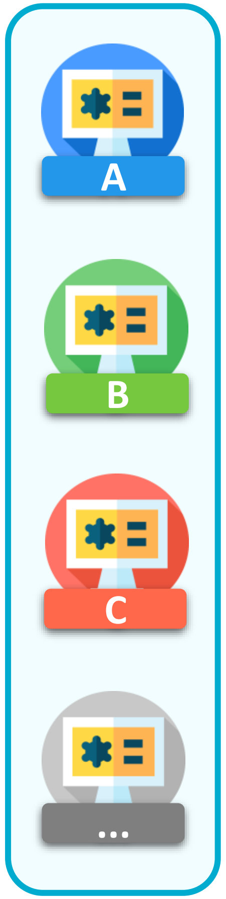
Tool types

- Web portals
- Interactive maps
- Interactive plots
- GIS applications
- Statistical libraries
- Custom model software
- ...

Common standards

- HTML5, JavaScript
- OGC Web Map Service
- USGS RDB
- CUAHSI WaterOneFlow
- OGC SOS
- Python language
- ...

Tools

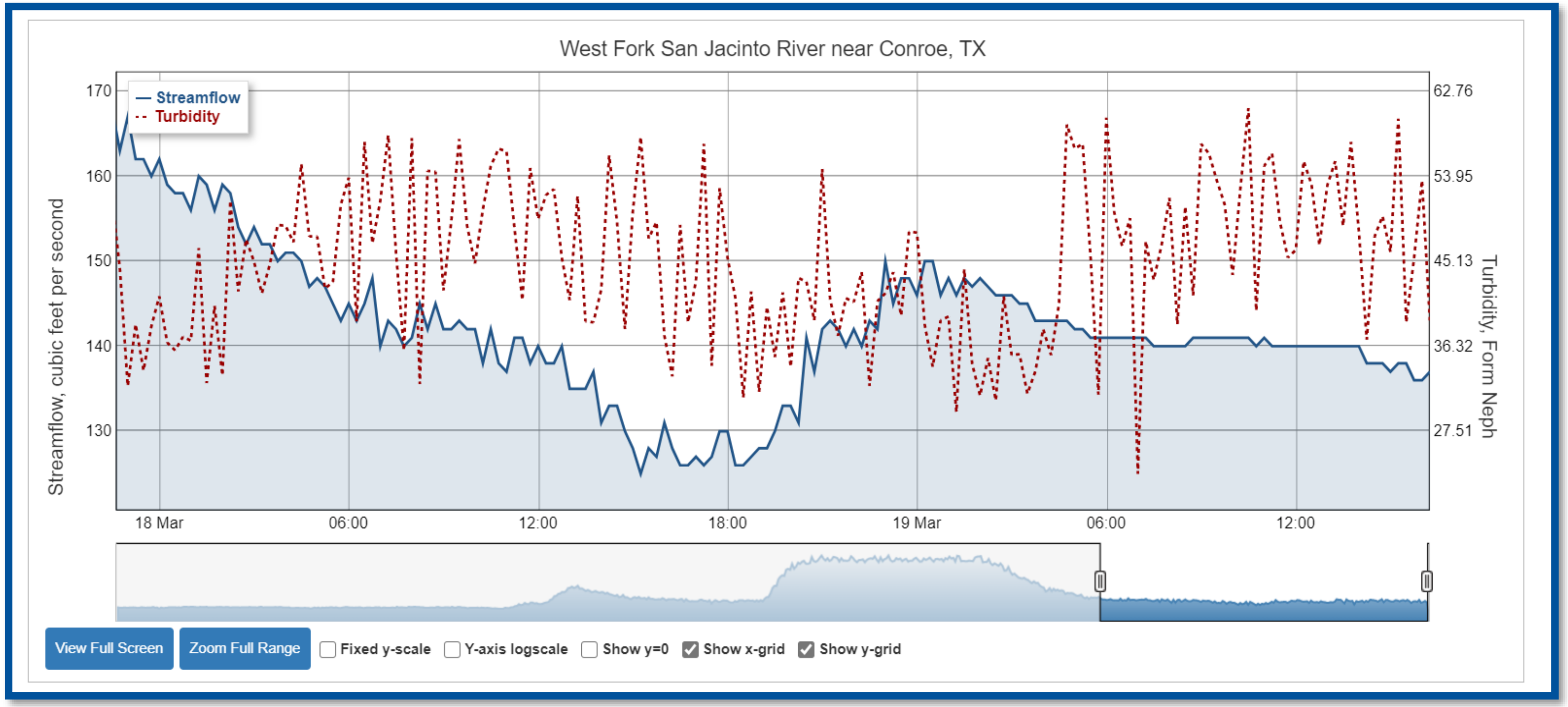


User Community: **General public**

Needed Functionalities	Tool types	Standards (examples)	Tools (examples)
Data consultation	**Web portals**	• HTML5, JavaScript (JS)	**Browsers** • Chrome • Firefox • …
Data visualization	**Interactive maps**	• OGC Web Map Service	**JS map libraries** • OpenLayers • Leaflet • …
Data visualization	**Interactive plots**	• USGS Water Services • USGS RDB data model	**JS plot libraries** • USGS GWIS

Graphing Water Information System (GWIS)

GWIS allows data providers to easily insert one or more interactive plots of any current or historical data into their web portals:



For more information: https://txpub.usgs.gov/dss/gwis/0.0/doc/#overview

User Community: **Data analysists community**

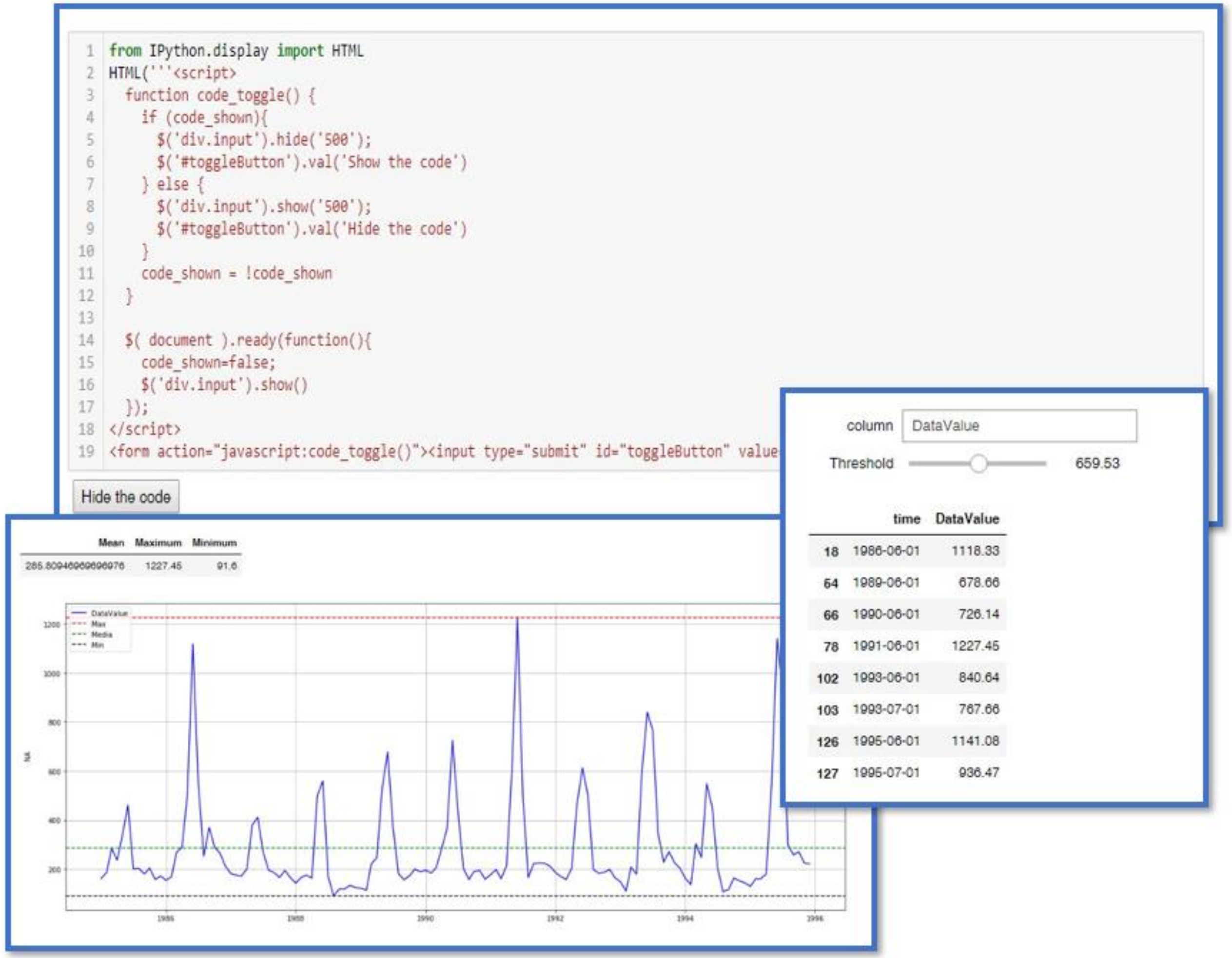
Needed Functionalities	Tool types	Standards (examples)	Tools (examples)
Data processing	**Custom applications making use of statistical libraries**	• Python language	• **Jupyter Notebook**
Data visualization		• MATLAB language	• **MATLAB** • **Octave**
Data analysis		• R (programming language)	• **R-project**

Jupyter notebooks

Uses include:

- data cleaning and transformation,
- numerical simulation,
- statistical modeling,
- data visualization,
- machine learning,
- ...

Jupyter website: https://jupyter.org/

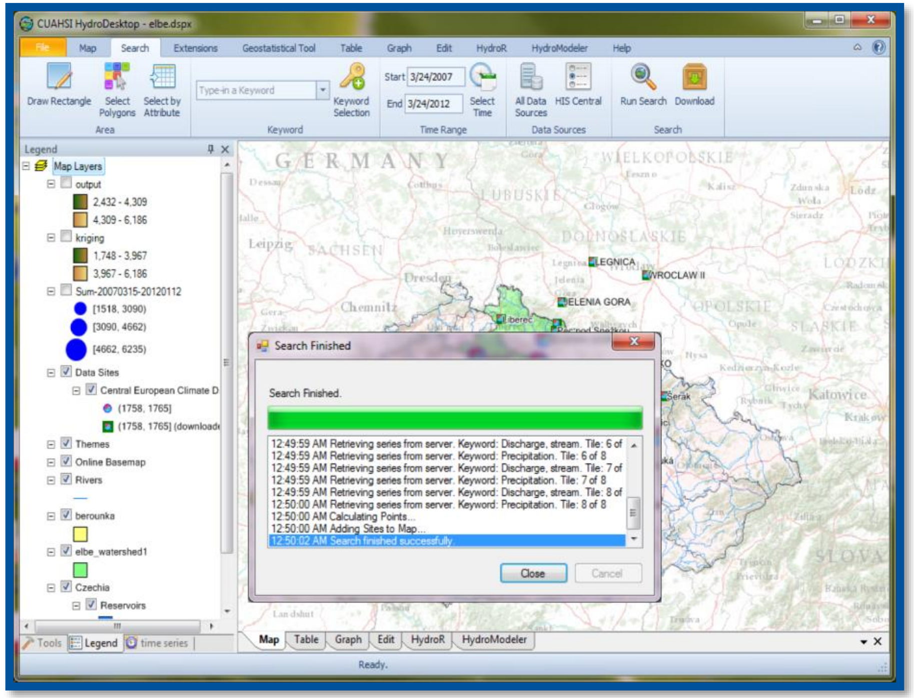


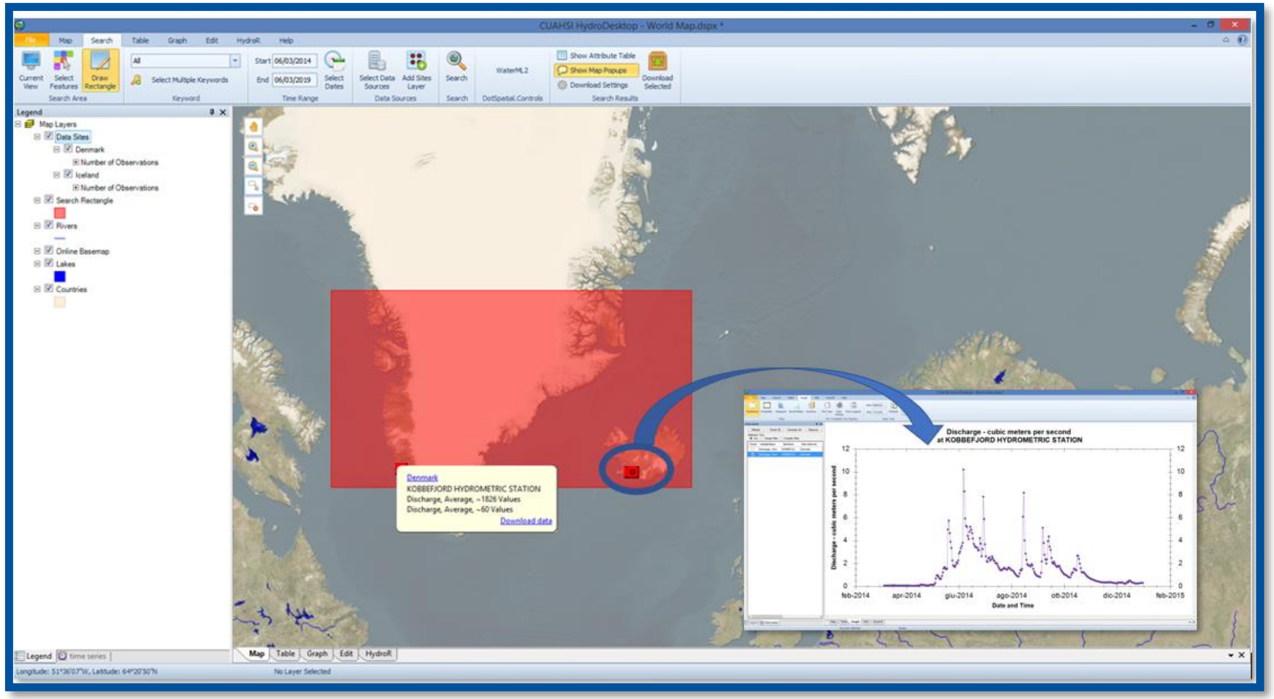
User Community: **Decision support**

Needed Functionalities	Tool types	Standards (examples)	Tools (examples)
Data discovery Data access Data visualization	**Hydro GIS applications** (allowing data discovery, access and visualization through user interfaces)	• **CUAHSI WaterOneFlow** (web service protocol) • **WaterML 1.0** data model	• CUAHSI HydroDesktop
		• **OGC Sensor Observation Service** (web service protocol) • **Observations & Measurements** data model	• QGIS

CUAHSI HydroDesktop

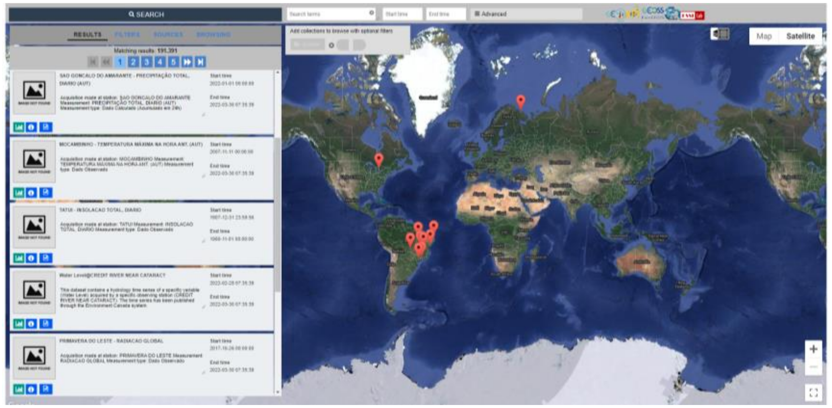
an application that helps you search for, download, visualize, and analyze hydrologic and climate data



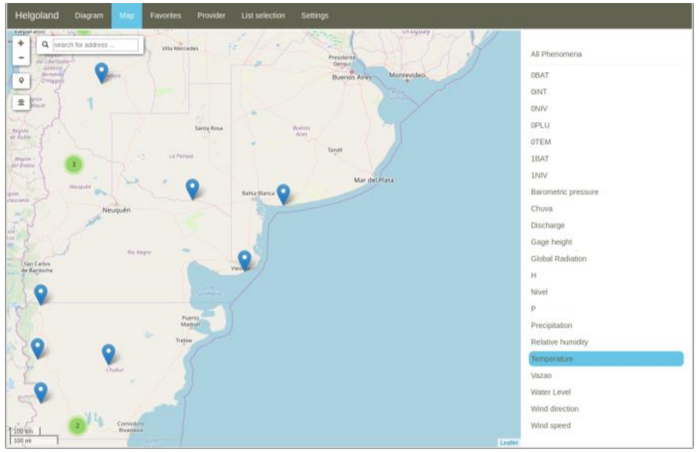


GitHub

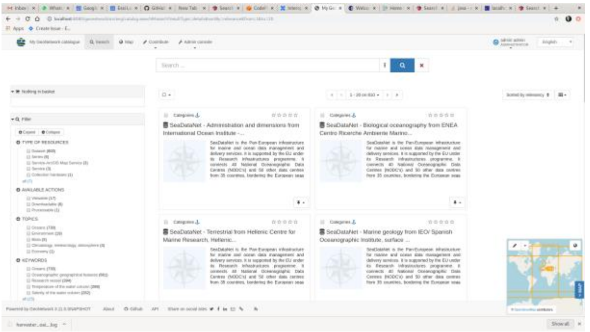
CUAHSI HydroDesktop is available on GitHub: https://github.com/CUAHSI/HydroDesktop



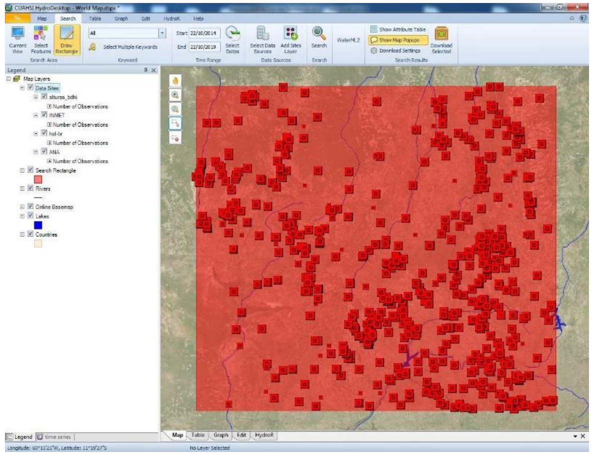
GI-portal



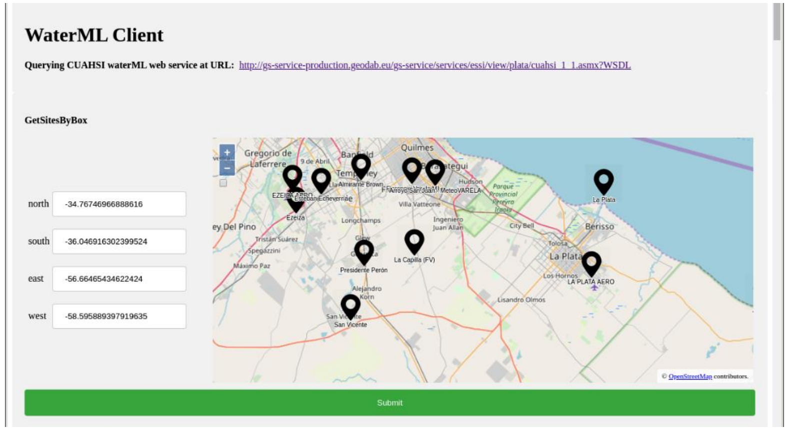
52North Helgoland



Geonetwork



CUAHSI HydroDesktop



WaterML Client

Jupyter notebooks

Node.js

R library

Open API Specification

Swagger

REST API

OGC services

C# WCF plugin

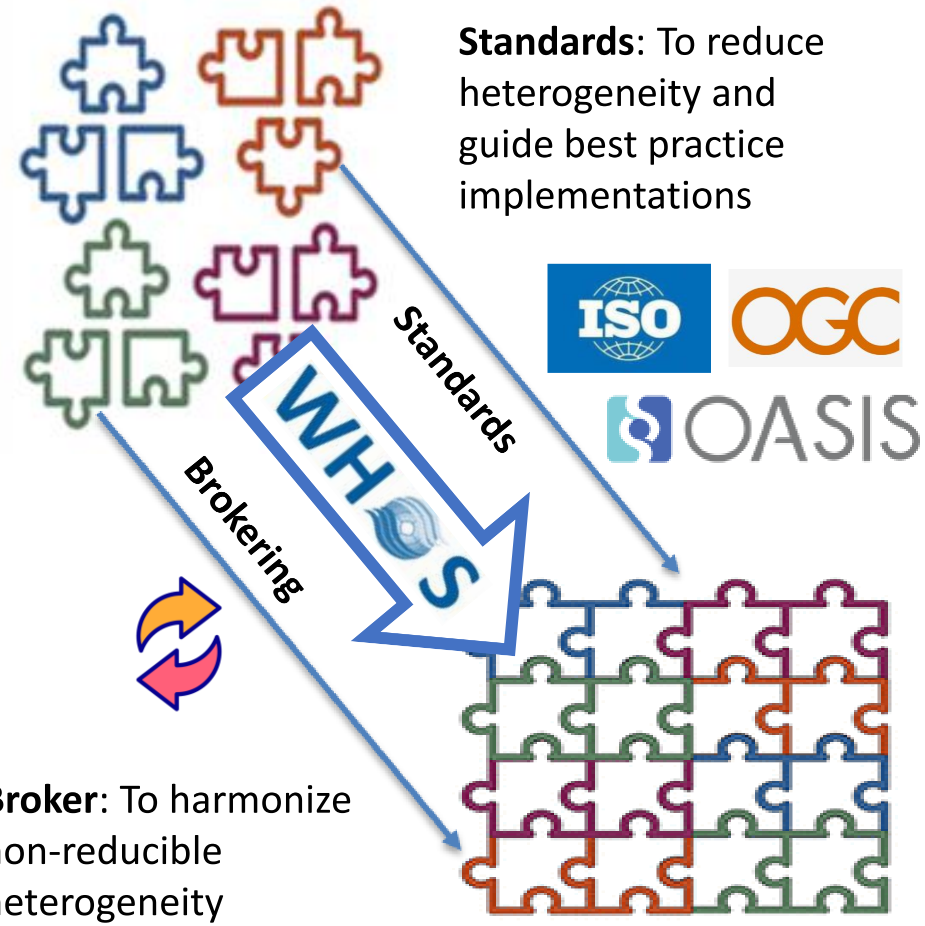
Support for developers

Market

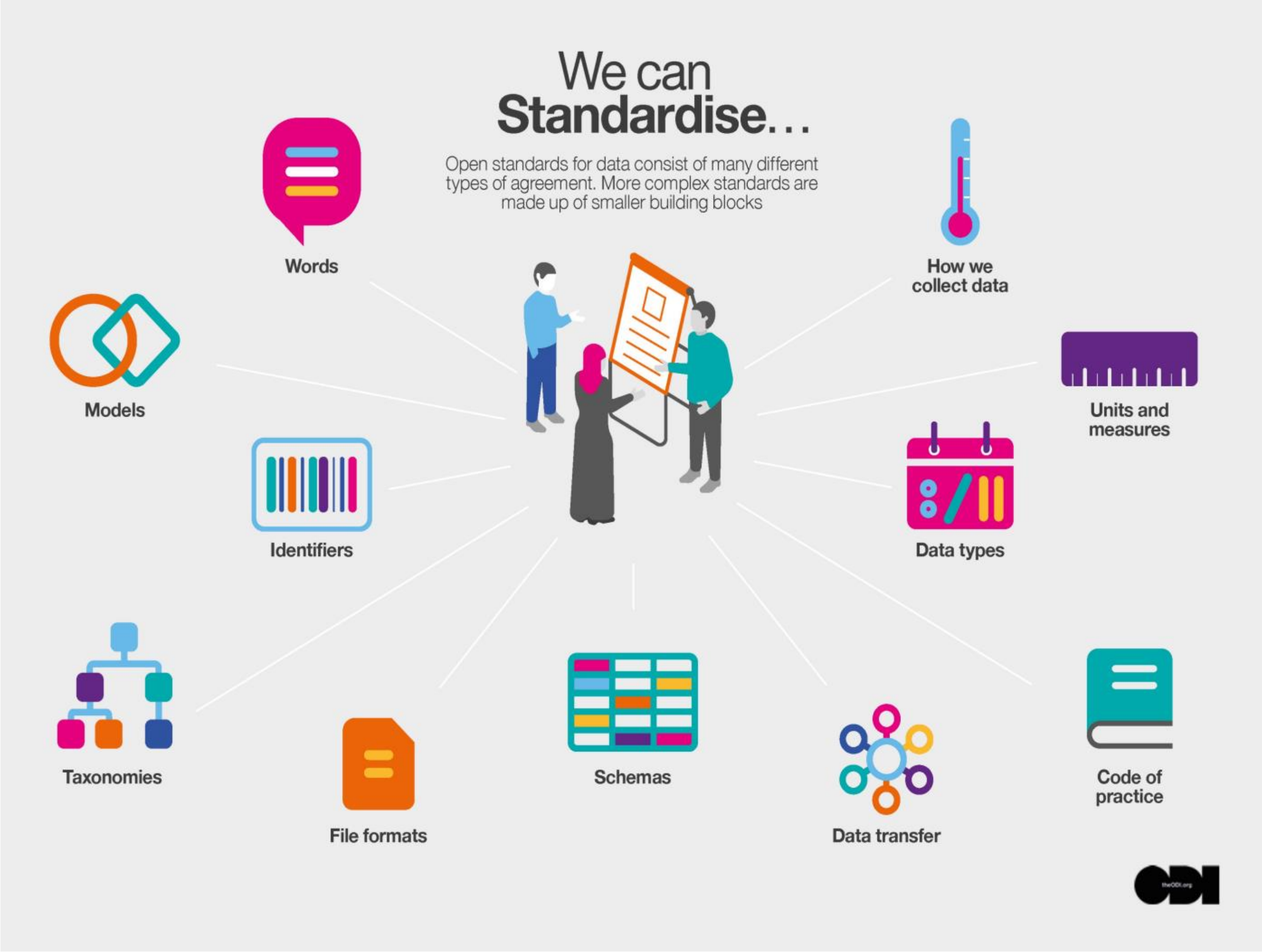
WHOS broker

WHOS pillars to support hydrology

Standards: To reduce heterogeneity and guide best practice implementations



Broker: To harmonize non-reducible heterogeneity

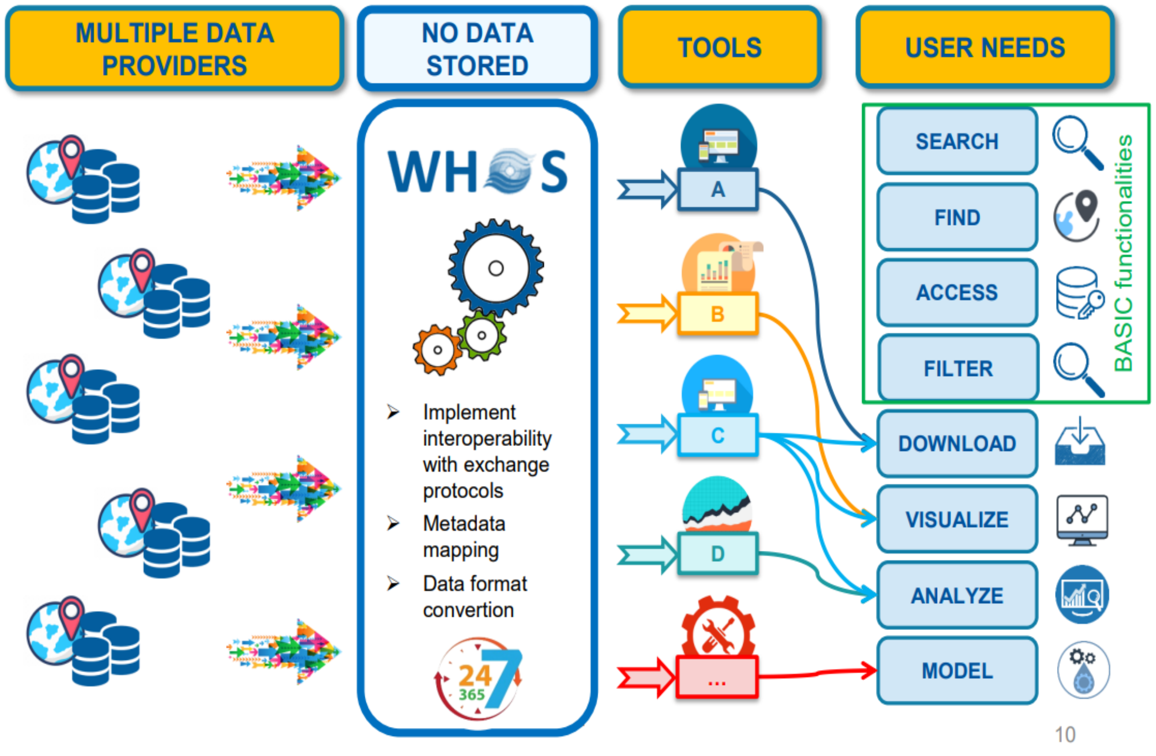


The Open Data Institute

Capacity building + use and promotion of **open standard and tools**

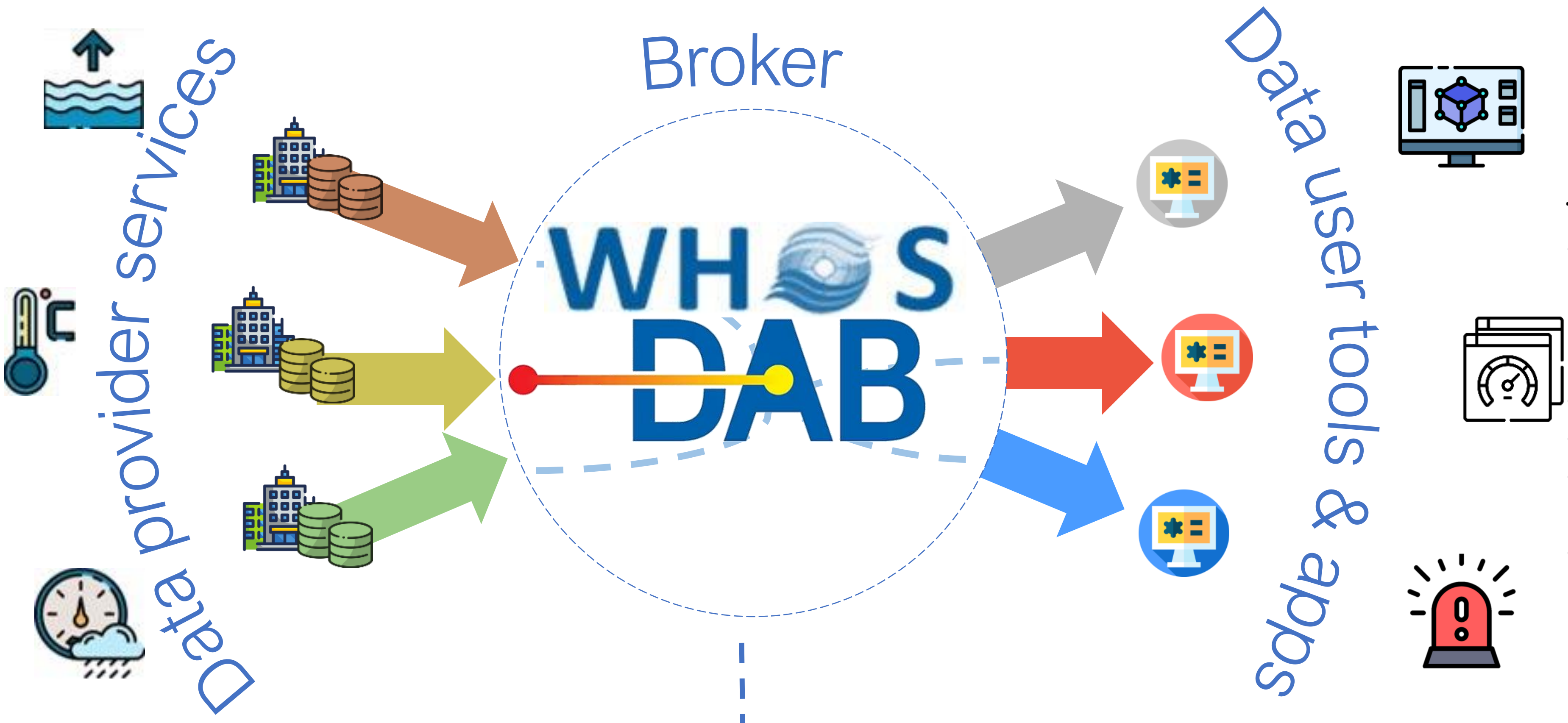
WMO Hydrological Observing System (WHOS)

- Solution for hydrological data discovery and access at global, regional and local scales using open standards and free tools started in 2018.
- Builds on top of exisisting systems; **lowers entry barrier** for data provider & data consumers by implementing a **brokering approach**.
- It enables outreach to other communities building bridges between domains (e.g. hydro and meteo) by means of interoperability between heterogeneous services
- Supports
  - ❑ WMO Plan of Action for Hydrology 2022 – 2030
  - ❑ WMO Unified Data Policy (Res 1, (Cg-Ext(2021)), International Exchange of Earth System Data
  - ❑ HydroSOS, WIGOS, WIS
  - ❑ Early Warnings For All; pillar 2 and key action area 4



Actors
- NMHS
- Private sector
- Research entities
- …

Publication systems
- WIS node
- Hydroserver
- THREDDS
- OGC SOS
- FTP
- …



Actors
- Modelers
- Hydrologists
- Researchers
- Decision makers
- …

Tools
- Portals
  - Water Data Explorer
- Forecast models
- Dashboards
- Alerting systems
- …

Hydrology domain:
- Concepts
- Relations
- Translations

WHOS Hydro ontology

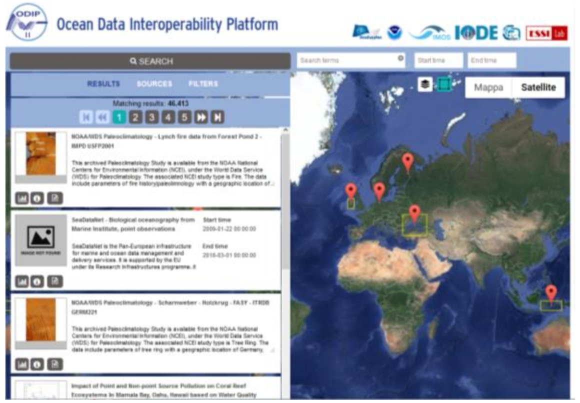
https://github.com/ESSI-Lab/DAB

Successful DAB deployments

https://wde.hydro.geodab.eu/apps/water-data-explorer-whos/

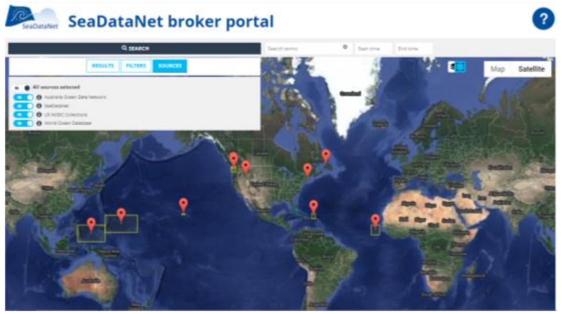
WHOS Global Portal

WMO Hydrological Observing System (WHOS)



http://gs-service-production.geodab.eu/gs-service/odip/search

Ocean Data Interoperability Platform (ODIP)



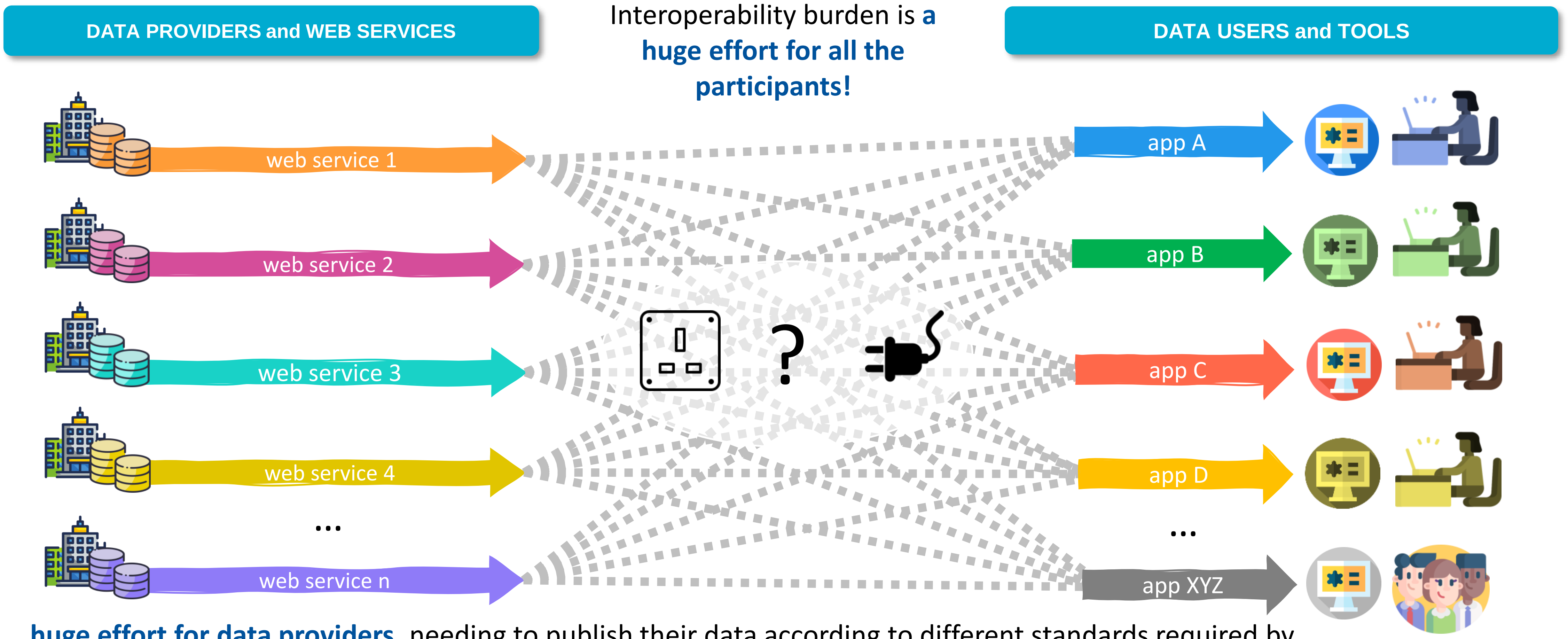
https://seadatanet.geodab.eu/gs-service/seadatanet-broker/search

SeaDataNet broker Portal (SeaDataNet)

https://www.geoportal.org/

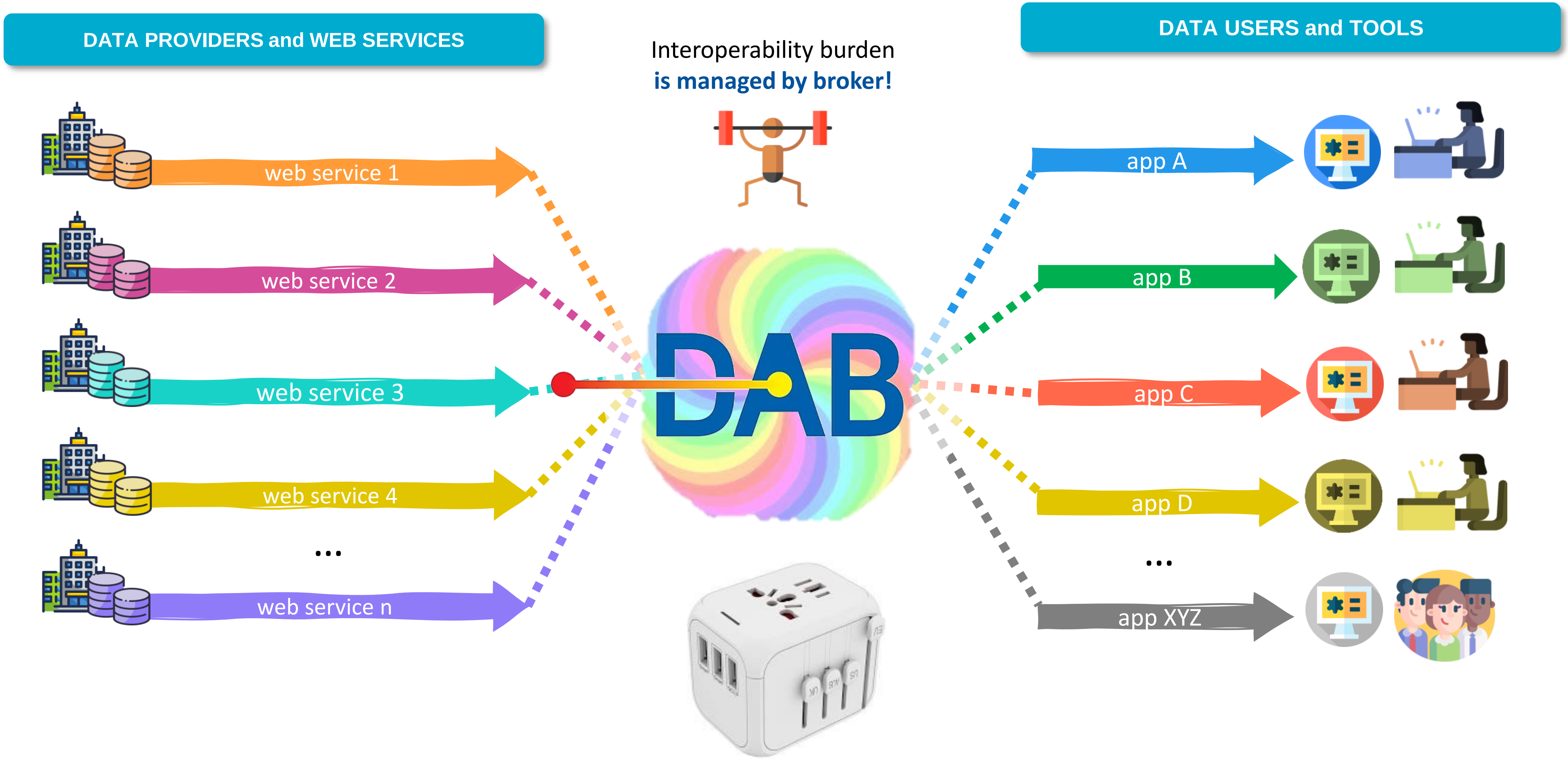
GEO Portal

Global Earth Observation System of Systems (GEOSS)



...**huge effort for data providers**, needing to publish their data according to different standards required by the different applications

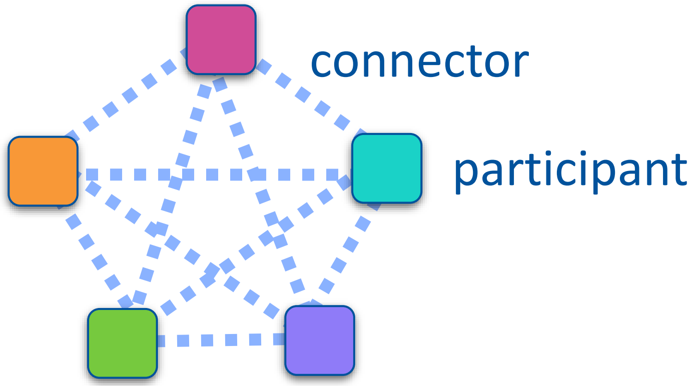
...**huge effort for data users,** needing to access data published according to different standards by the different data providers

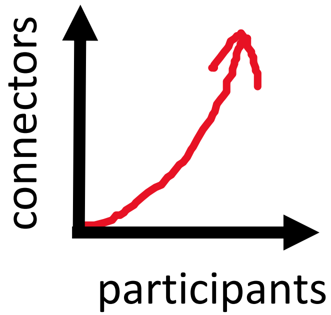


it works like a power adapter …for hydrology!
Connecting data providers & data users regardless of the specific standards available

Standardization and brokering approaches

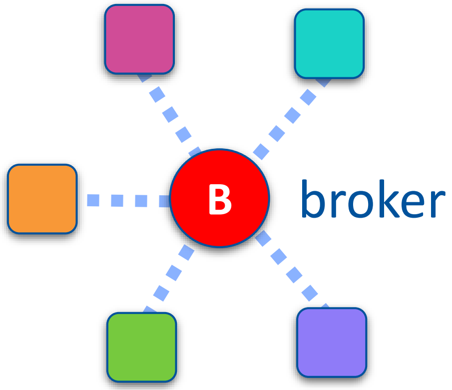
Brokering approach is not applied

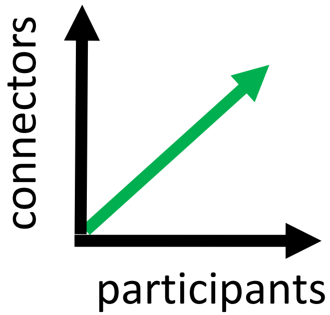




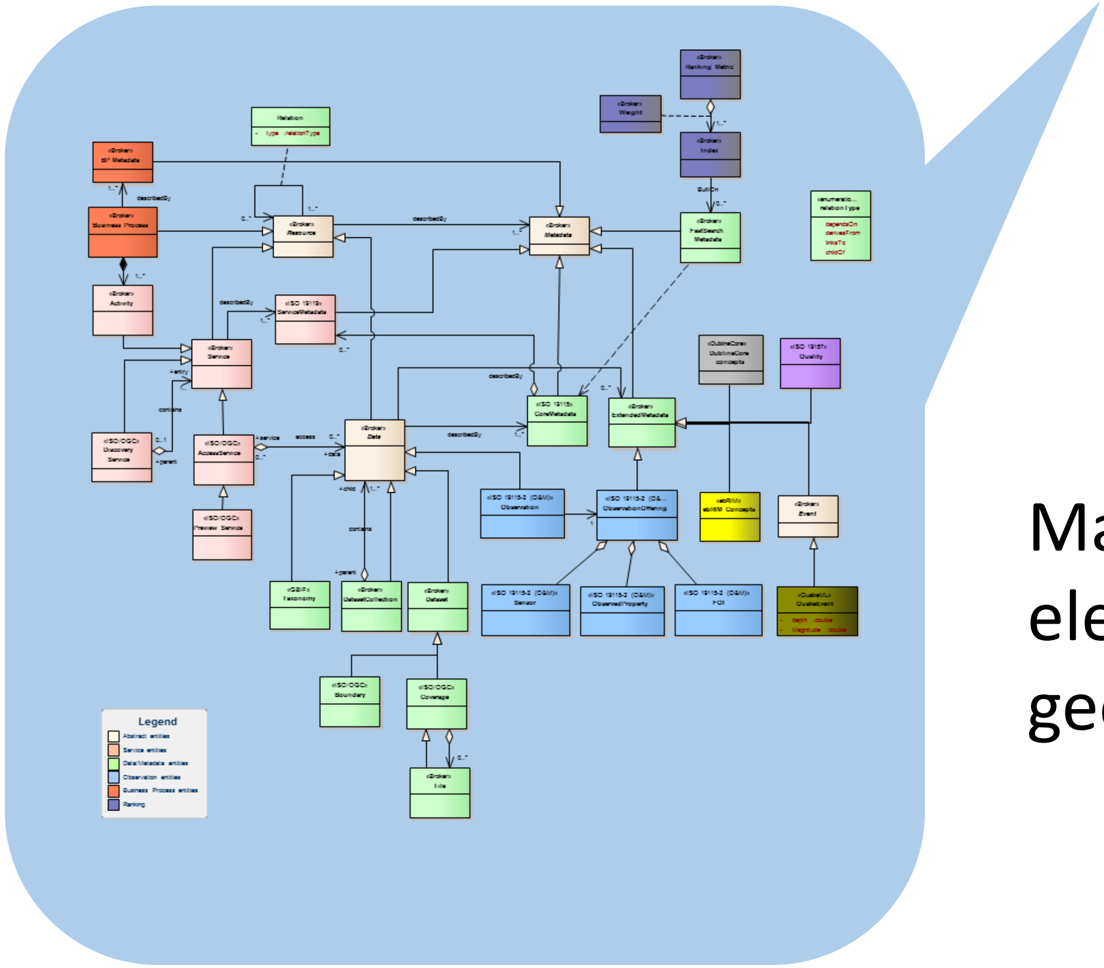
Number of needed connectors grows **very rapidly** with the number of participants!

Brokering approach is applied





Number of needed connectors grows **linear** with the number of participants.



DAB

Metadata model
Based on
ISO 19115
+ extensions
(e.g. WaterML)

} 400+ metadata elements

Make it possible to accommodate metadata elements from existing and future geographic **metadata models**

Data model
Based on
NetCDF-CF
+ extensions (e.g. WaterML)

The roles of the three WHOS brokers

Obtain **metadata**

Discovery:
search for the datasets that match a set of metadata elements

Discovery Broker

Enables data discovery from heterogeneous data providers by means of various applications

Augment **query**

Semantic discovery *(optional)*:
user augments its query with additional search terms from various ontologies

Semantic Broker

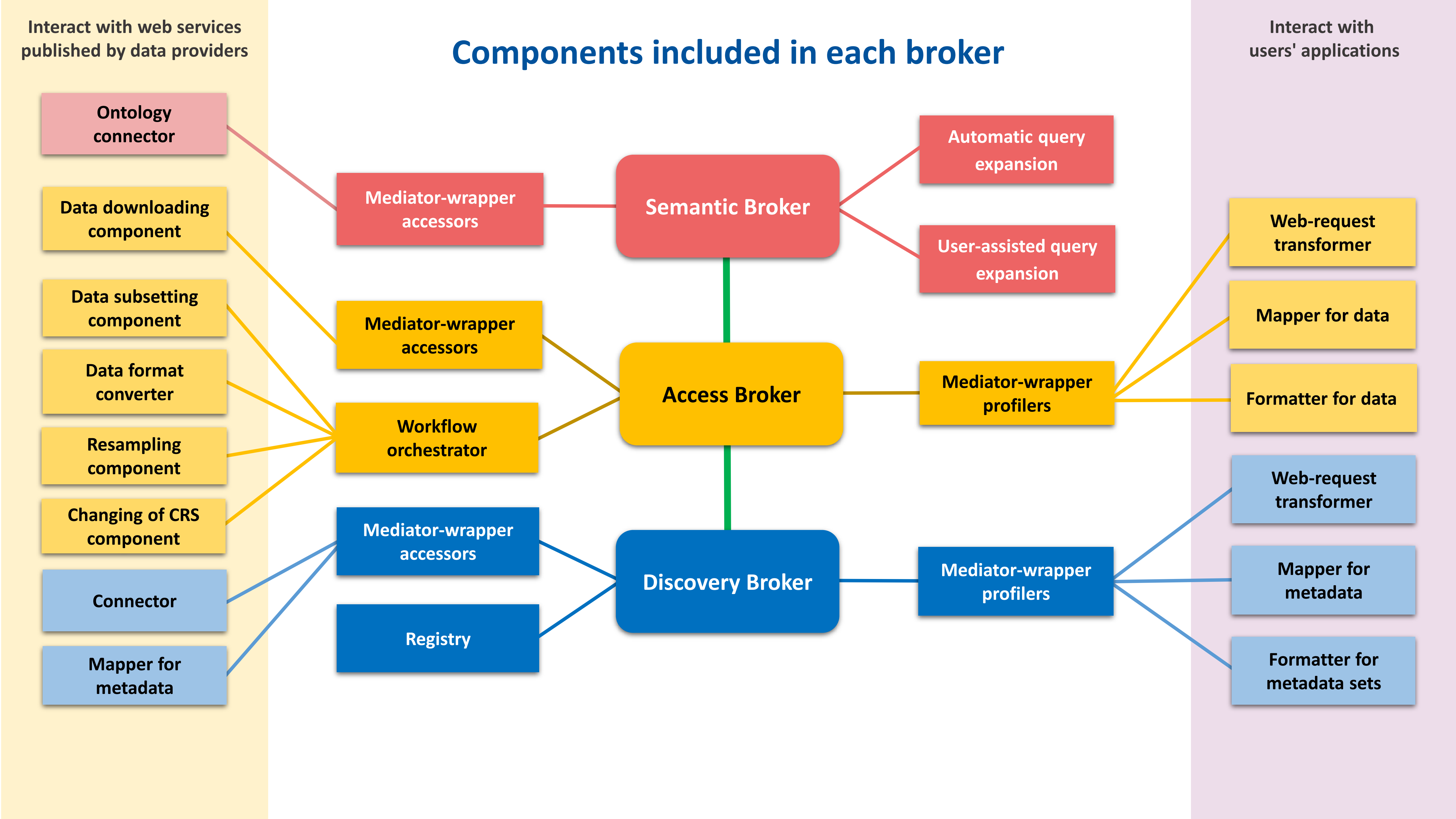
Queries for concepts and terms from various ontologies

Obtain **data**

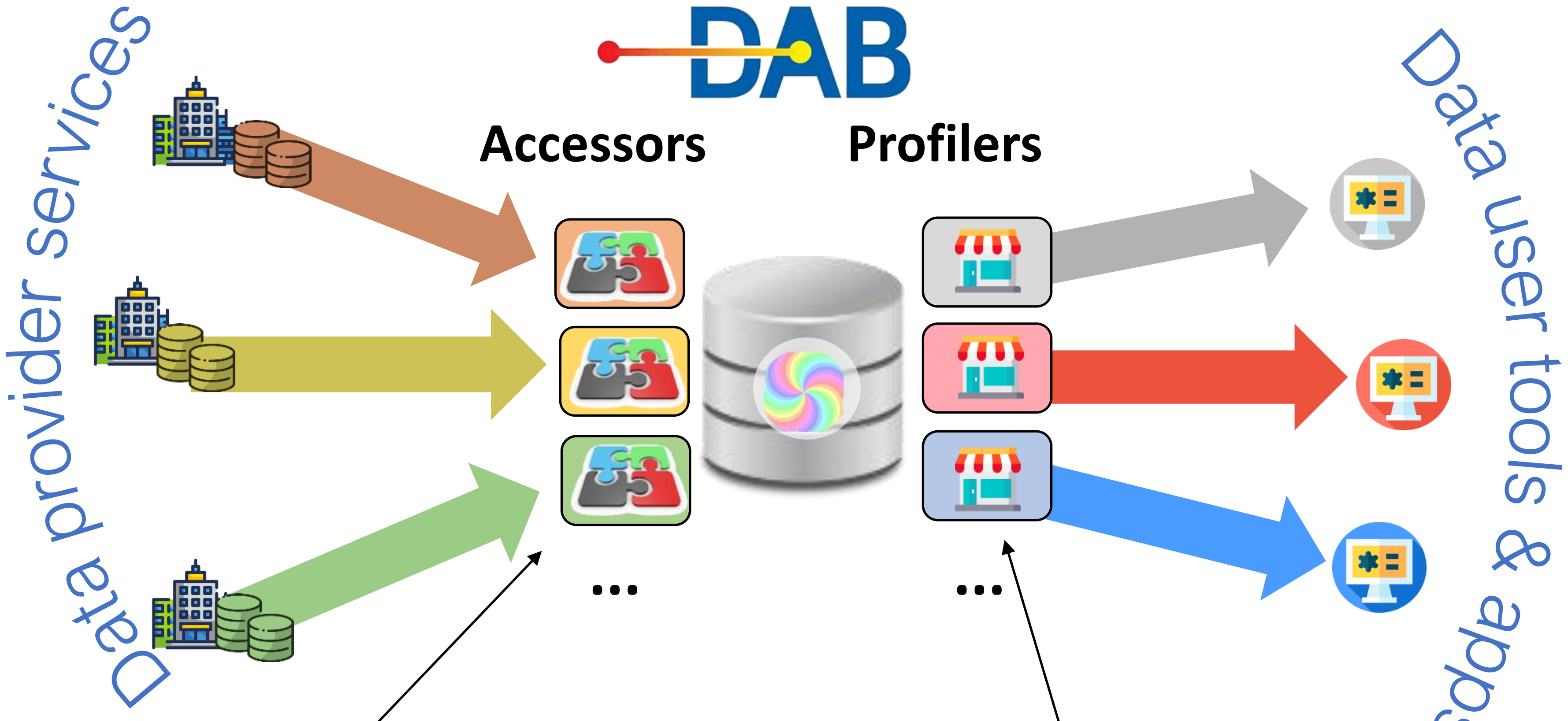
Access:
user requests to download the datasets that are the result of the discovery step

Access Broker

Enables data access from heterogeneous data providers by means of various applications

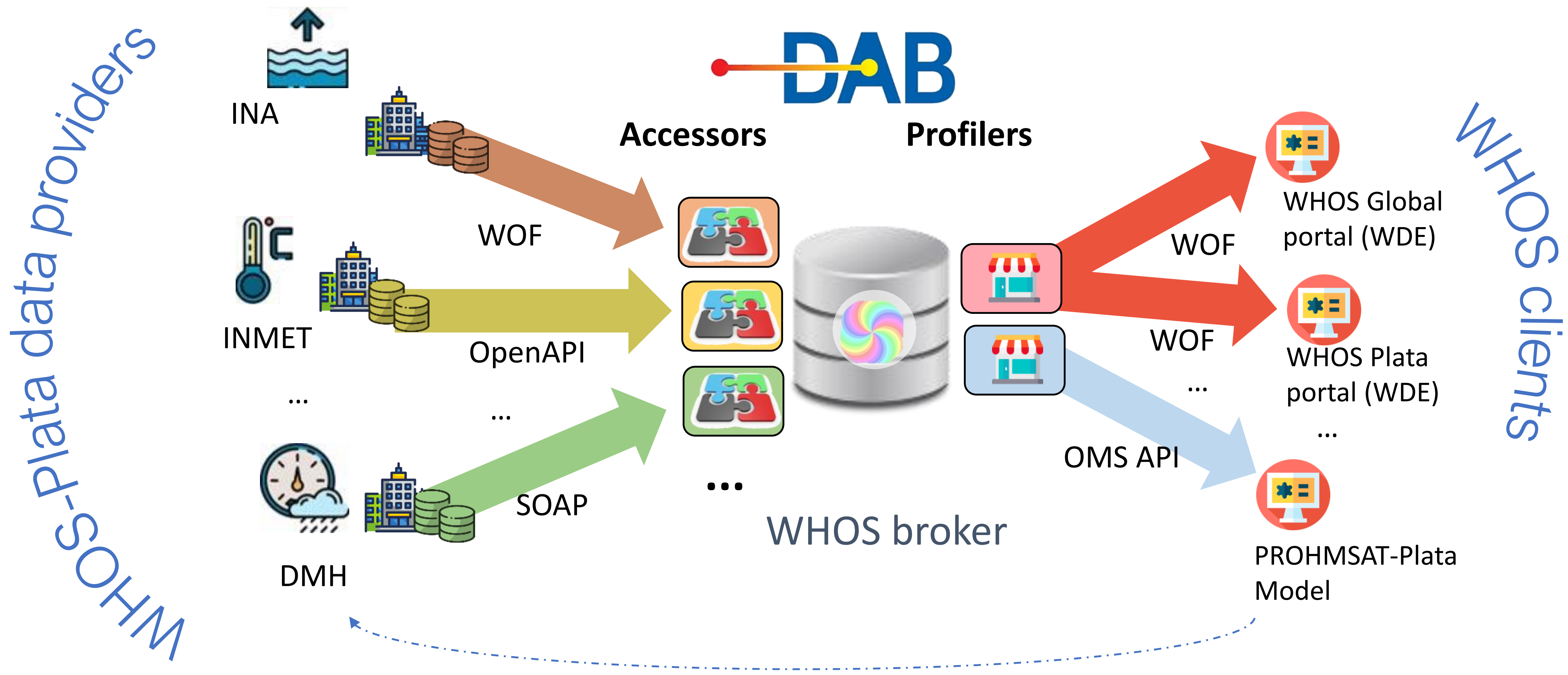


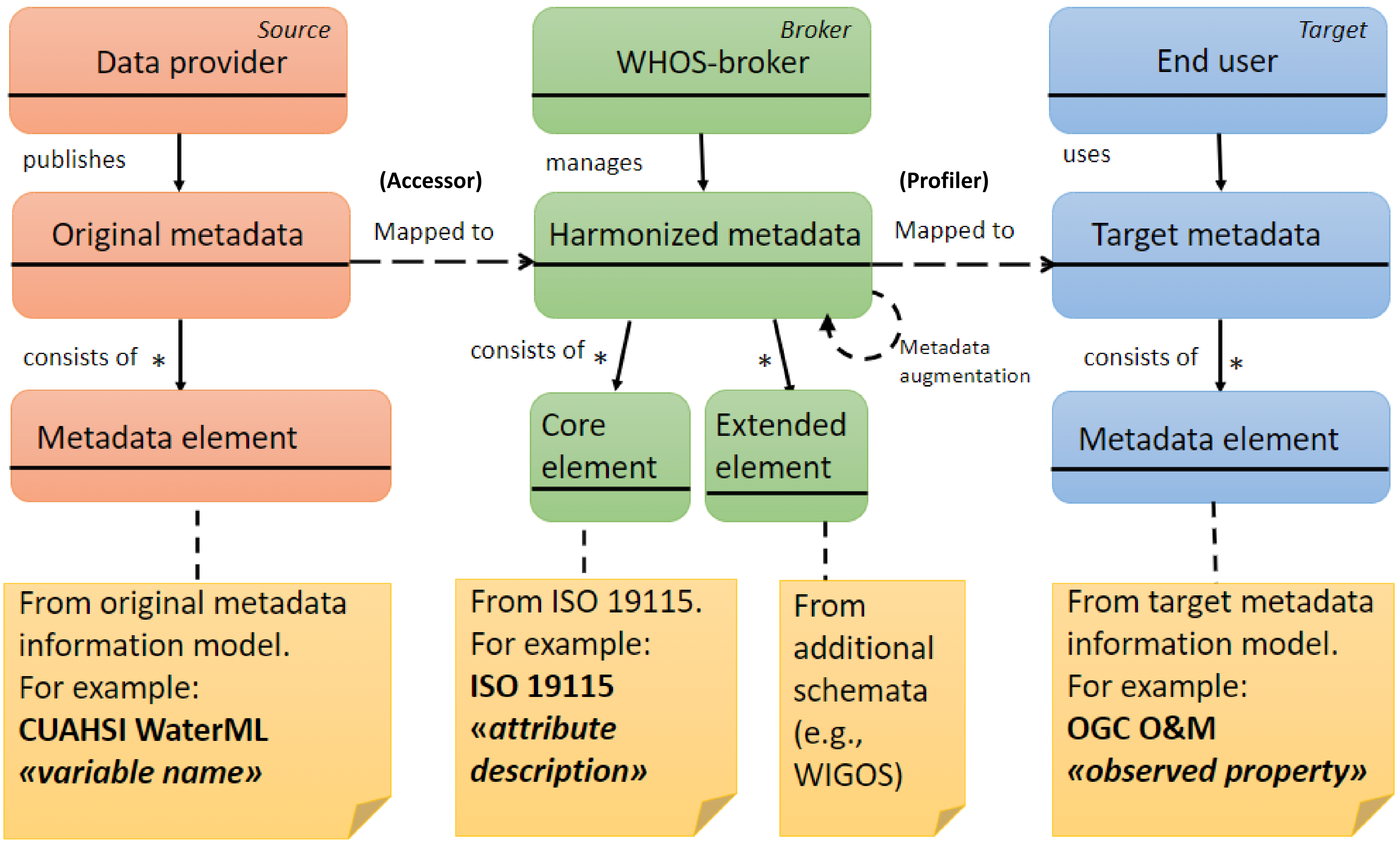
Interact with web services published by data providers
Components included in each broker
Interact with users' applications
Ontology connector
Data downloading component
Data subsetting component
Data format converter
Resampling component
Changing of CRS component
Connector
Mapper for metadata
Mediator-wrapper accessors
Mediator-wrapper accessors
Workflow orchestrator
Mediator-wrapper accessors
Registry
Semantic Broker
Access Broker
Discovery Broker
Automatic query expansion
User-assisted query expansion
Mediator-wrapper profilers
Mediator-wrapper profilers
Web-request transformer
Mapper for data
Formatter for data
Web-request transformer
Mapper for metadata
Formatter for metadata sets



- Support for specific data provider communication protocol
- Mediation of specific data provider metadata model towards DAB harmonized metadata model

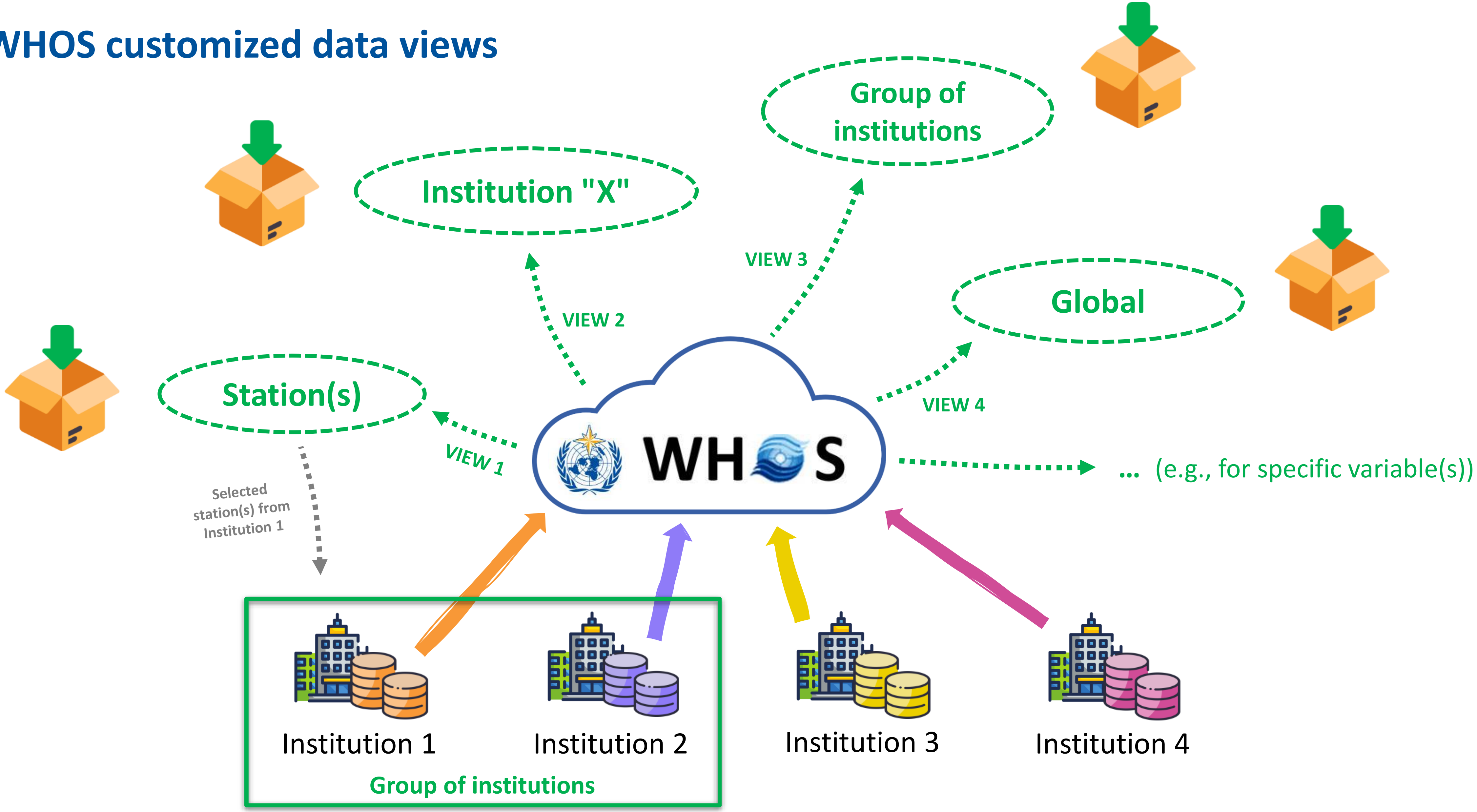
- Implement protocols required by specific apps
- Mediation from DAB harmonized metadata model to metadata models required by specific apps


WHOS-Plata data providers
INA
INMET
...
DMH
WOF
OpenAPI
...
SOAP
DAB
Accessors
Profilers
...
WHOS broker
WOF
WOF
...
OMS API
WHOS Global portal (WDE)
WHOS Plata portal (WDE)
...
PROHMSAT-Plata Model
WHOS clients



Source
Data provider
publishes
Original metadata
consists of *
Metadata element
From original metadata information model. For example: **CUAHSI WaterML** ***«variable name»***
Broker
WHOS-broker
manages
(Accessor)
Mapped to
Harmonized metadata
consists of *
*
Core element
Extended element
Metadata augmentation
From ISO 19115. For example: **ISO 19115** ***«attribute description»***
From additional schemata (e.g., WIGOS)
Target
End user
uses
(Profiler)
Mapped to
Target metadata
consists of *
Metadata element
From target metadata information model. For example: **OGC O&M** ***«observed property»***

WHOS customized data views



Example WHOS regional views

WHOS-Plata

5 countries:
Argentina, Bolivia, Brazil, Paraguay, Uruguay

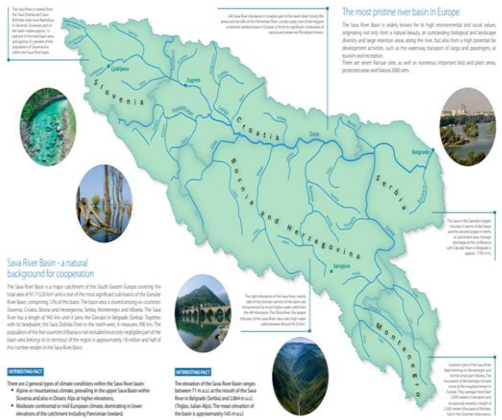
WHOS-Arctic

5 countries:
Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, the United States of America

WHOS-Dominican Rep.

1 country:
Dominican Republic

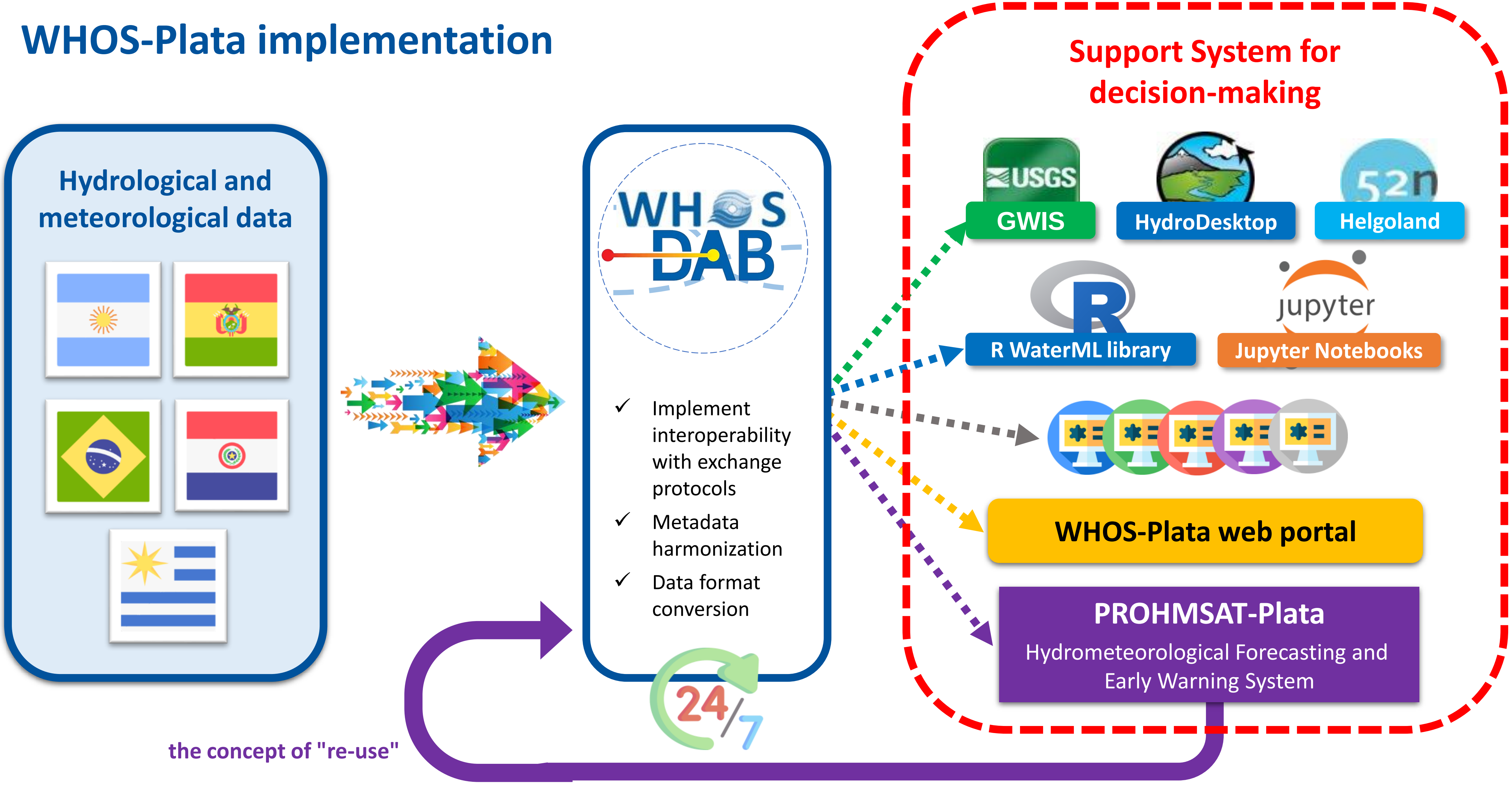
WHOS-Sava



4 countries:
Bosnia and Herzegovina, Republic of Croatia, Republic of Serbia, Republic of Slovenia

Total: 18 countries freely exchanging and reusing hydrometeorological data in an interoperable way for national, regional and global purposes

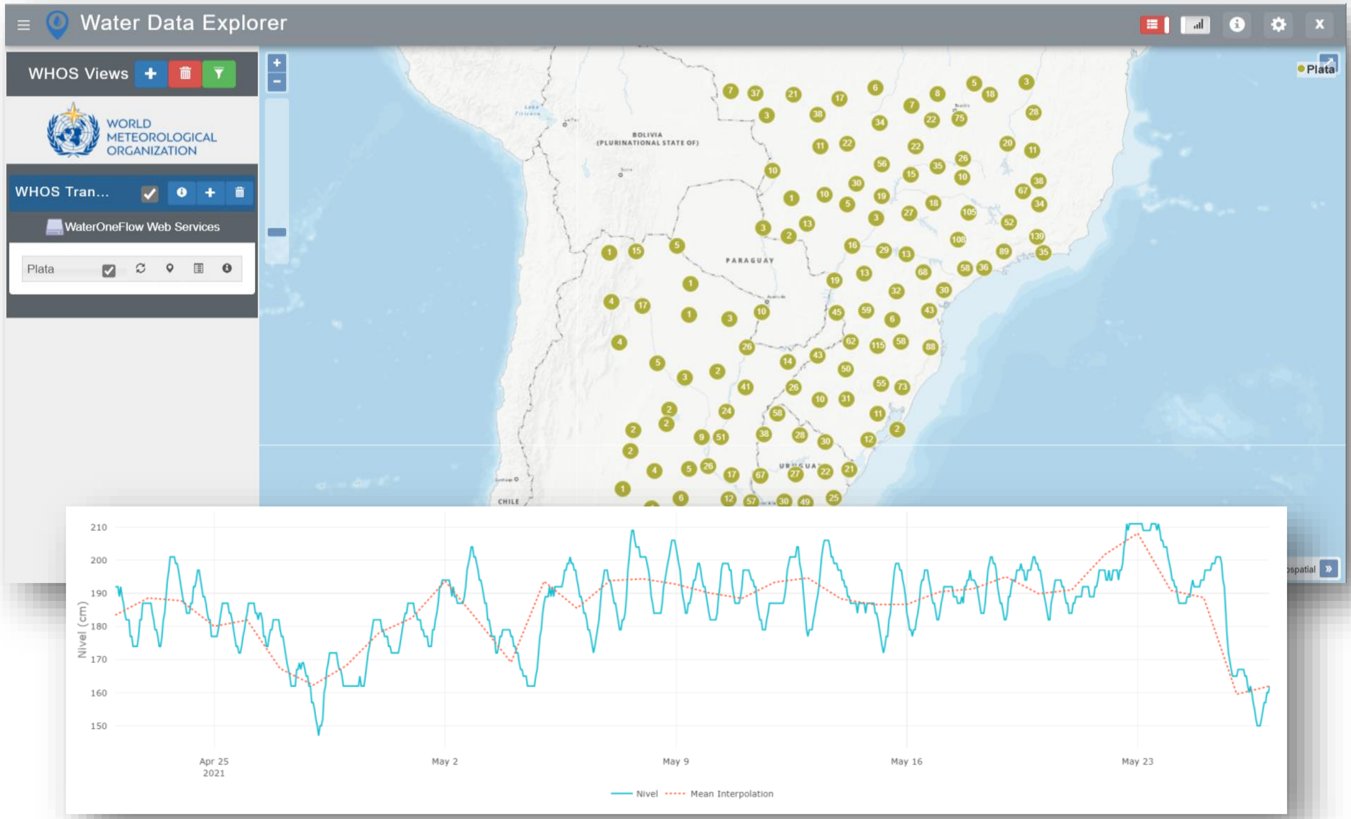
WHOS-Plata implementation

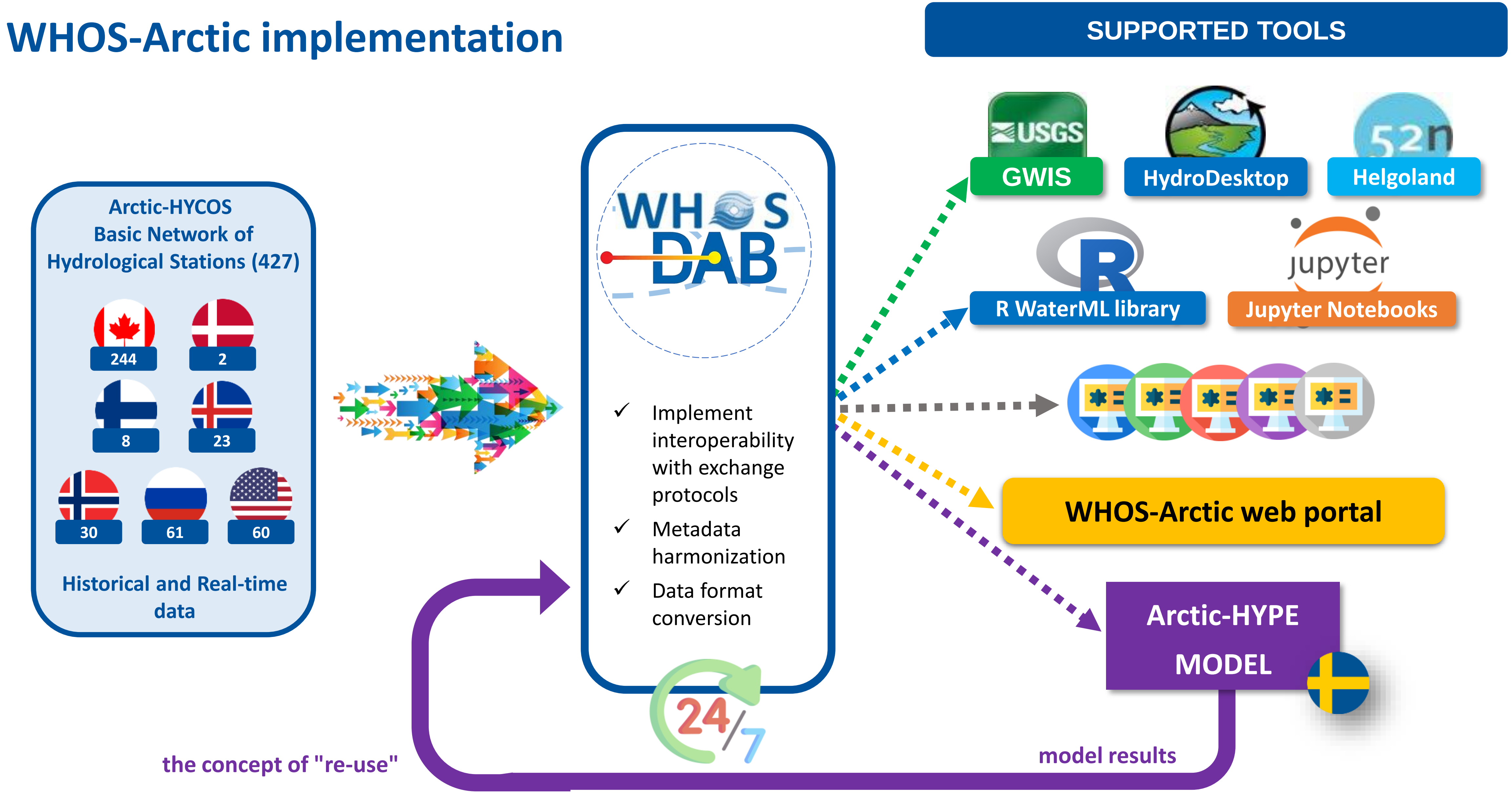


WHOS-Plata web portal

http://tethys.inmet.gov.br/

WHOS-Plata

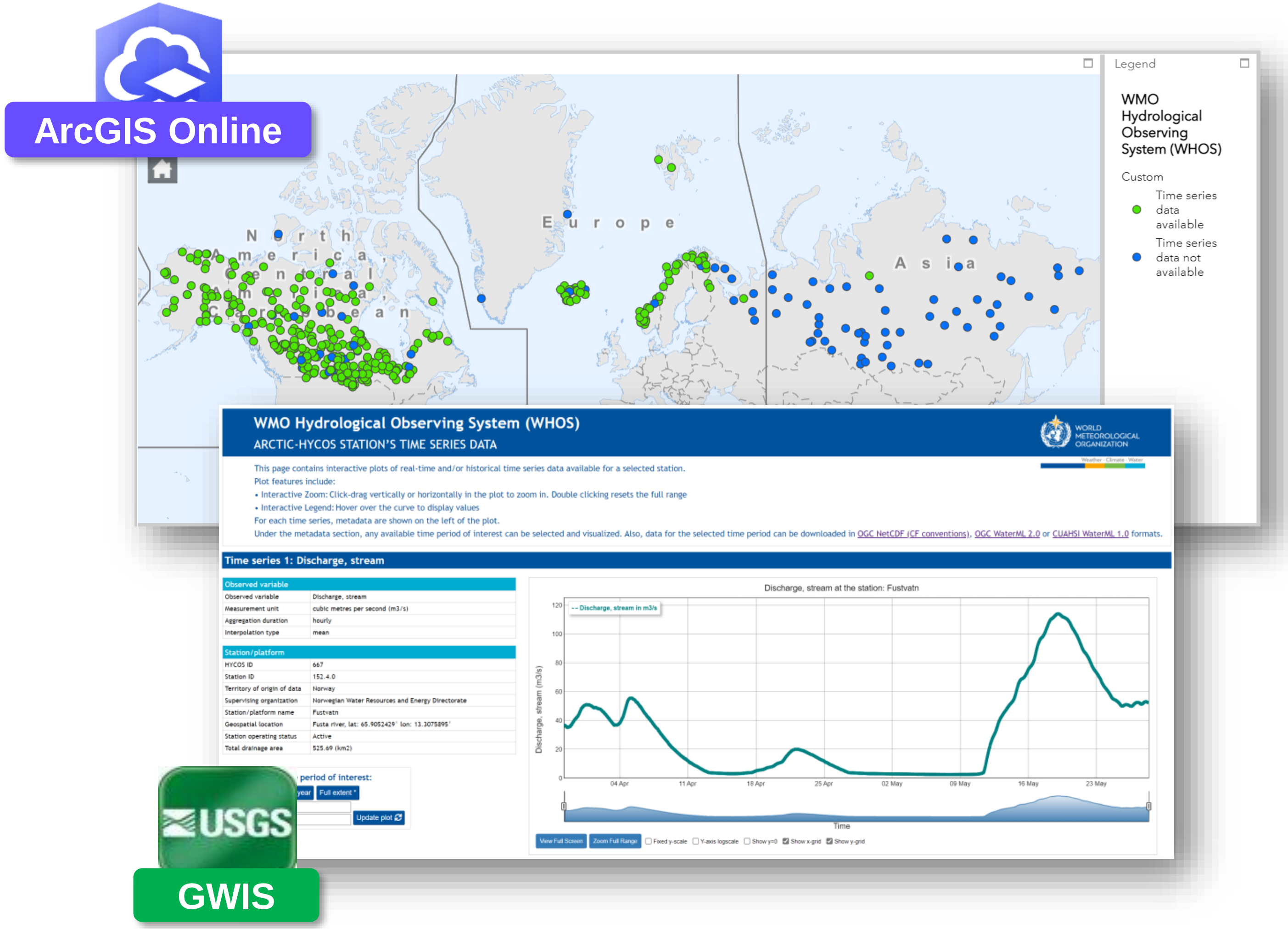



WHOS-Arctic implementation
SUPPORTED TOOLS
Arctic-HYCOS
Basic Network of
Hydrological Stations (427)
244
2
8
23
30
61
60
Historical and Real-time data
WHOS DAB
Implement interoperability with exchange protocols
Metadata harmonization
Data format conversion
24/7
USGS
GWIS
HydroDesktop
52n
Helgoland
R
R WaterML library
jupyter
Jupyter Notebooks
WHOS-Arctic web portal
Arctic-HYPE MODEL
model results
the concept of "re-use"

WHOS-Arctic web portal

https://hydrohub.wmo.int/en/projects/Arctic-HYCOS

WHOS-Arctic



WHOS-Arctic

1. Canada,
2. Finland,
3. Denmark (for Greenland),
4. Iceland,
5. Norway, Russia
6. USA,

Global Data Centers

GRDC

IGRAC

WHOS-SAVA

7. Slovenia
8. Croatia
9. Bosnia and Herzegovina
10. Serbia,
11. Montenegro

WHOS-La Plata

12. Argentina
13. Bolivia
14. Brazil
15. Paraguay
16. Uruguay

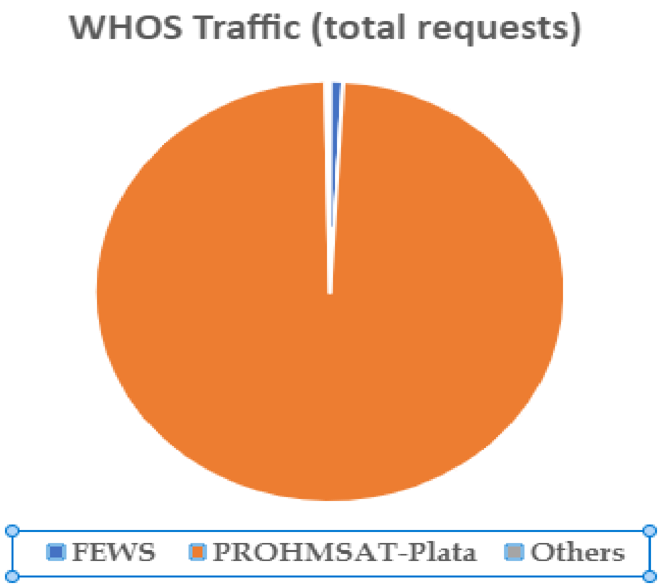
Countries

17. UK (NRFA)
18. Italy (ISPRA)
19. New Zealand (NIWA)
20. Dominican Republic

Ongoing Implementation

- **Contribution to GEOSS**
- **Contribution to EMODnet Physics**

Additional sources: Togo, South Africa, Niger, CUAHSI HIS, Chile

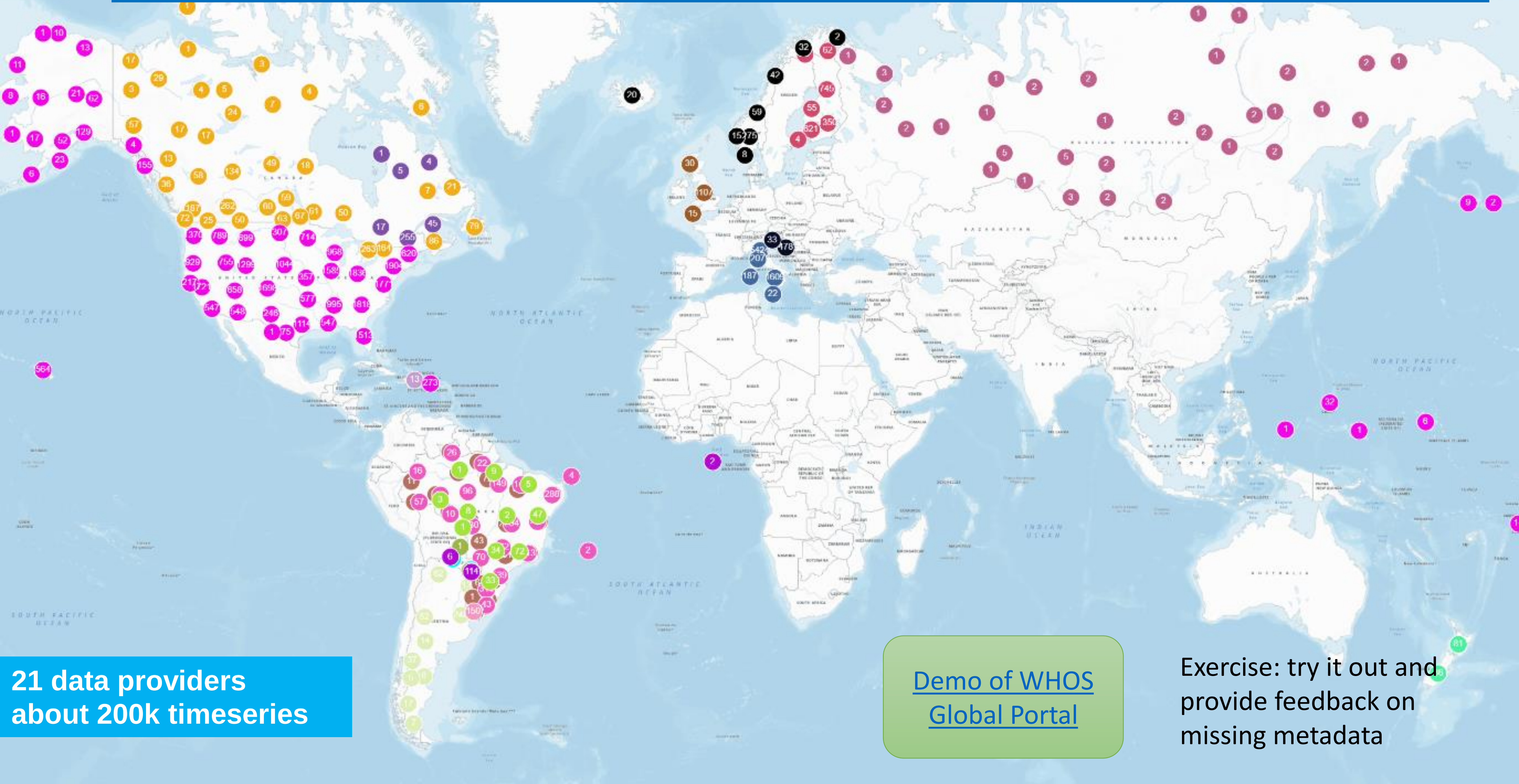


1100059 **122211317** **376602**

Current Number of timeseries: about 200k

WHOS implementations and usage so far

WHOS Global Portal (by 15.12.2023)



21 data providers
about 200k timeseries

[Demo of WHOS Global Portal]

Exercise: try it out and provide feedback on missing metadata

WHOS resources at WMO

https://community.wmo.int/activity-areas/wmo-hydrological-observing-system-whos

DISCOVER AND ACCESS DATA

Click to expand

[-]

- WHOS Portals
- WHOS web services and supported tools

WHOS-Global Portal

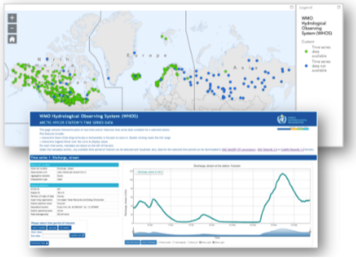
WHOS-Global Portal provides all hydrometeorological data shared through WHOS. WHOS-Global Portal is implemented using the Water Data Explorer application.

WHOS-Plata Portal

WHOS-Plata Portal provides hydrometeorological data collected in the La Plata river basin and shared by Argentina, Bolivia, Brazil, Paraguay and Uruguay. WHOS-Plata Portal is implemented using the Water Data Explorer application.

WHOS-Arctic Portal

WHOS-Arctic Portal provides hydrometeorological data shared by Canada, Finland, Denmark (for Greenland), Iceland, Norway, Russia and the United States of America for the Arctic-HYCOS Basic Network of Hydrological Stations (BNHS). WHOS-Arctic Portal is implemented using ArcGIS Online for the map interface and USGS GWIS (Graphing Water Information System) for the time-series plots.



WHOS portals

Scientific paper on WHOS-DAB

Enrico Boldrini, Stefano Nativi, Silvano Pecora, Igor Chernov & Paolo Mazzetti (2022) **Multi-scale hydrological system-of-systems realized through WHOS: the brokering framework**, International Journal of Digital Earth, 15:1, 1259-1289, DOI: 10.1080/17538947.2022.2099591

WHOS documentation at WMO

https://community.wmo.int/activity-areas/wmo-hydrological-observing-system-whos

DISCOVER AND ACCESS DATA

Click to expand

[-]

- WHOS Portals
- WHOS web services and supported tools

Supported standards

OAI-PMH, CUAHSI WOF, OGC SOS, OGC CSW, OpenSearch, USGS RDB, DAB API, ESRI Feature Service, ...

Supported technologies

Oscar, Geonetwork, HydroDesktop, Water Data Explorer, R WaterML library, PyWaterML library, WCF C# plugin, Node.js WaterML client, 52North Helgoland, GI-suite JS API, ESRI ArcGIS online, ...

WHOS PARTICIPATION

Click to expand

[-]

- Sharing new data through WHOS
- Connecting a new tool to WHOS
- Distance Learning Course

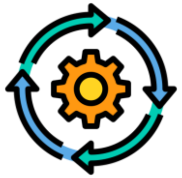
How a data provider can join WHOS

https://community.wmo.int/activity-areas/wmo-hydrological-observing-system-whos

Technical requirements

1) Setup an online data sharing system

2) Provide its URL to WHOS



3) Implementation & feedback to/from data provider

Implement WMO Unified Data Policy

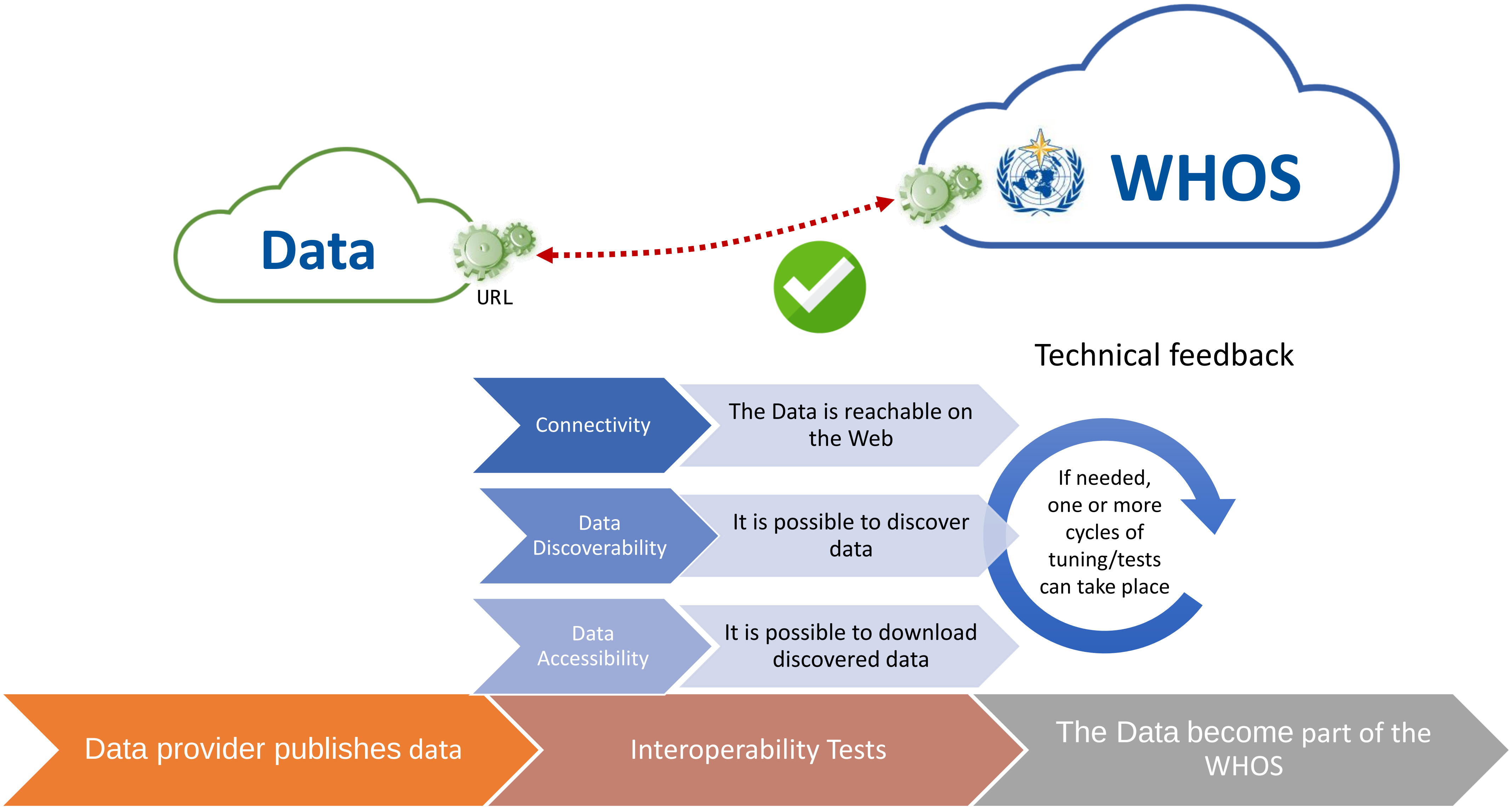
Data sharing policy:

- **Metadata** publication is mandatory
- For **data** depending on its type:
  - **Core** data: Free and unrestricted (Global caches, scientific communities)
  - **Recommended**: Restricted and limited access data (NMHS-NC, regional/RBOs/LBOs, DCPC, Hydrology centers)

These centers can create two endpoints: one for core data and another for recommended or implement access control in their services.

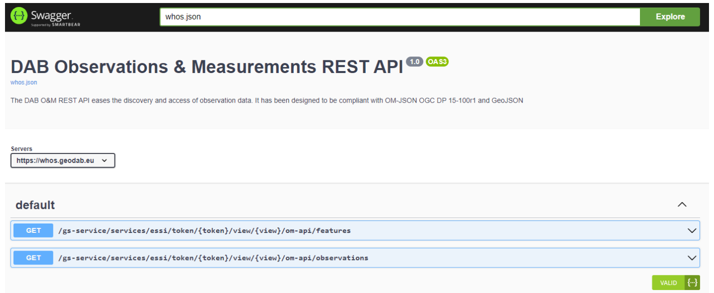
core

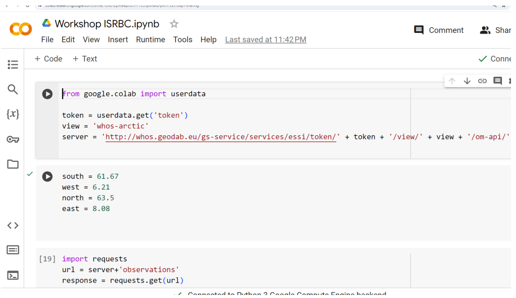
recommended

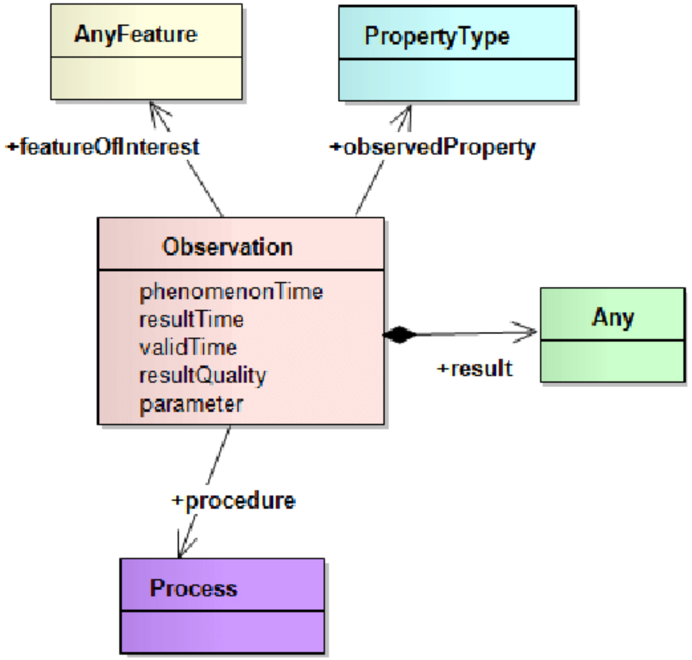


Connecting new data providers - process

Programmatic access exercise (O&M API & Python notebook)

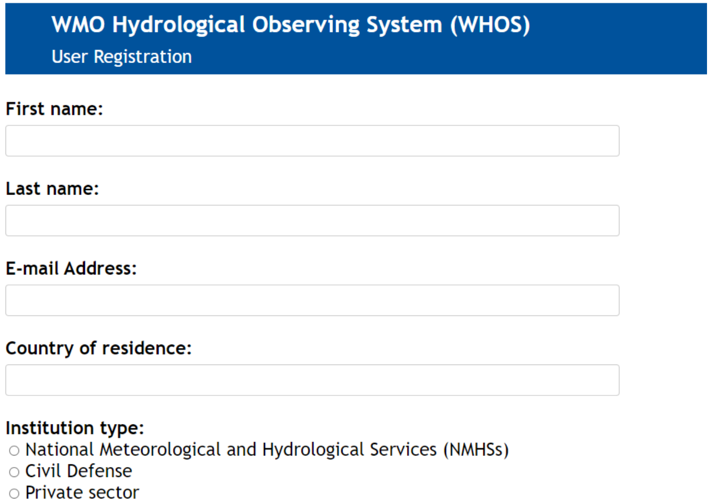






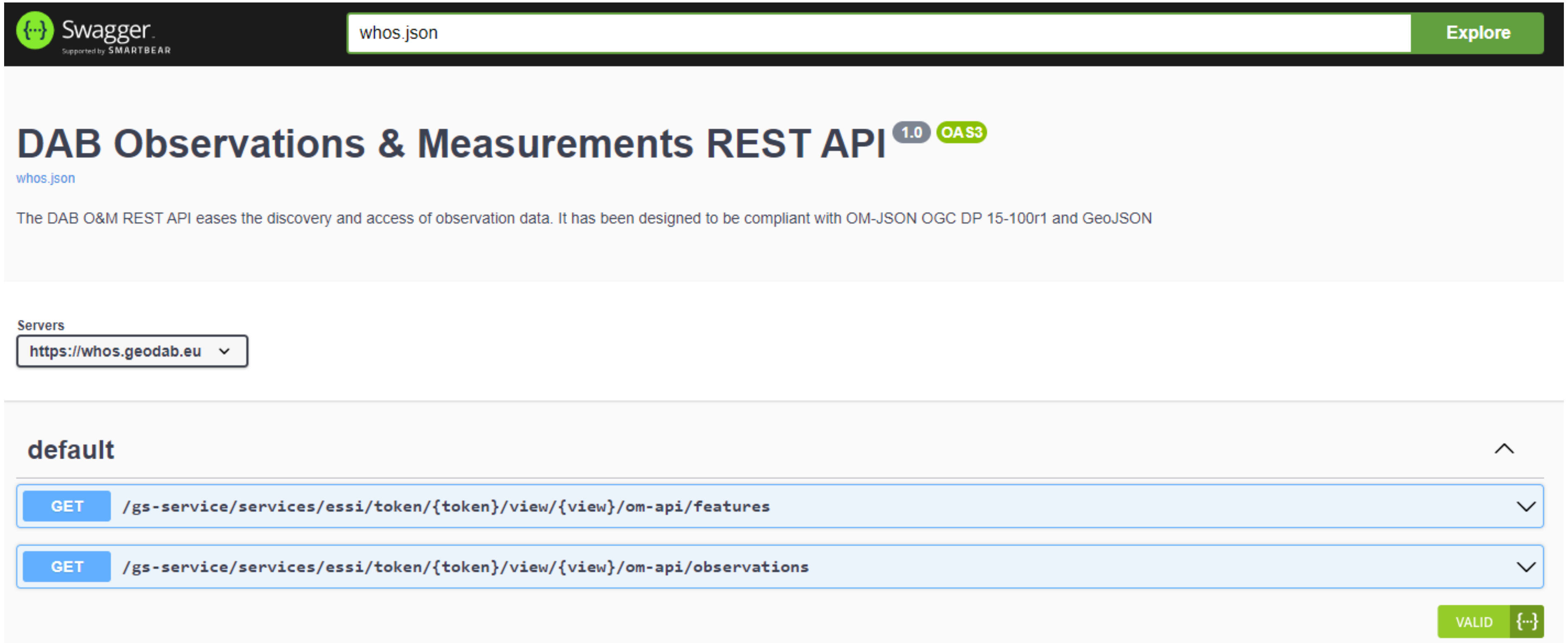
Required parameters:

- View (e.g. whos-plata, whos-arctic, …)
- Token (register at: https://whos.geodab.eu/gs-service/whos/registration.html)



Observations and Measurements model main classes

Programmatic access (API)



Exercise: test out the API through the online client

Required parameters:

- View
- Token

REST interface, with two resources:

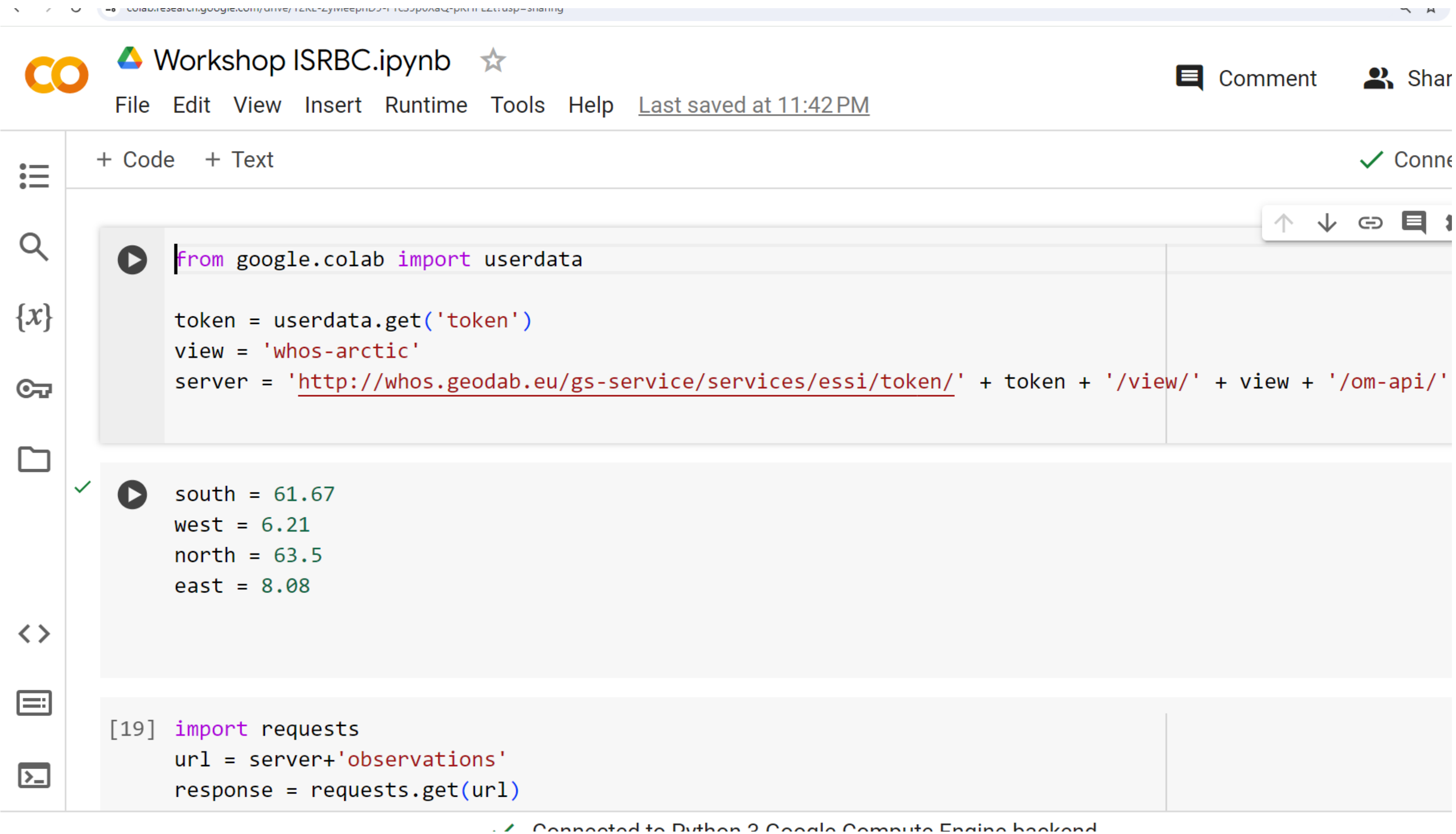
- Features (sampling features, e.g., monitoring points)
- Observations (e.g., time series: both metadata and values)

https://whos.geodab.eu/gs-service/om-api/whos.html

Resources can be queried:

- By id
- By spatial-temporal extent
- By observed property (using ontology)
- By aggregation duration, observation spacing
- By country
- …

Programmatic access (Python notebook)



Exercise: expand the notebook to retrieve values and plot

http://tinyurl.com/colab-isrbc

VISIT WHOS Site: Link to WHOS Site

Contact Us: **whos@wmo.int**