Strengthening of R in support of spatial data infrastructures management

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Introduction

- Spatial Data Infrastructure (**SDI**) ~ set of components:
  - **Data repository**: spatial database, shapefiles, etc.
  - **Geographic Data Server**: one or more datastores exposing data resources on the web
  - **Metadata Catalogue**: set of metadata sheets describing data resources

- Programmatic tools for **Spatial Data Infrastructure (SDI)** management?
  - Two types of tools:
    - **standard-related** (eg ISO, OGC, OpenDAP, EML)
      → Need to familiarize with standards
      → versioning / long lifecycle, stable, reproducible, sustainable?
    - **software-related** (eg GeoServer, GeoNetwork, Thredds)
      → Need to familiarize with software
      → versioning?, lifecycle?, stable… or not, reproducible (as long as the APIs do not change suddenly), sustainable?
  - Existing robust tools in other languages, eg Java *Apache SIS / GeoToolkit* for metadata, *geoserver-manager* for data publication, python *pygeometa*, *gsconfig* ….
  - … but hard to adopt for many data managers: reserved to a GIS IT specialized community

Introduction - XML ... 😱 😱 😱

- A good reason to be scared by GIS standards driving Spatial Data Infrastructures: There is a lot of XML (generally)
  - Example 1 - **ISO 19115 (Dataset metadata)**
    - XML
    - The “end product” (less scaring)
  - Example 2 - **ISO 19110 (Data structure definition)**
    - XML
    - The “end product” (less scaring)
- Even more scaring when we wonder how we could manage these kind of fiels with R? 😱 😱 😱 😱 😱 😱

Introduction

- Make tools for SDI management available in R for a targeting a wider data management community: **beyond IT community**
- Complementary to **spatial data handling** tools already available
  - sf, sp, rgeos, rgdal, raster, etc.
- Tools for:
  - **ISO/OGC standard geographic metadata handling**: write, read, validate, convert from other metadata formats (eg Ecological Metadata Language - EML, NetCDF-CF)

    → *geometa*
  - **OGC Web-Services (OWS) interaction**: including data and metadata services, with binding to *sf* (for data) and *geometa* (for metadata) → *ows4R* package
  - **Software-specific API interaction**: including data and metadata services, eg GeoServer API → *geosapi* package, GeoNetwork API → *geonapi* package
  - **Spatial Data Infrastructure orchestration** → *geoflow* initiative

geometa – Reading and Writing ISO/OGC Geographic Metadata

- Build an API in R for **writing**, **reading** and **validating** metadata sheets following ISO/TC211 and OGC metadata standards
- References
  - ISO standards (some also OGC standards):
    - ISO 19115 (Dataset metadata),
    - ISO 19119 (Service metadata),
    - ISO 19136 (Geographic Markup Language - GML 3.2.1)
    - ISO 19110 (Feature Catalog),
    - ISO 19139 (XML Implementation)
  - ISO 19139 profiles defined to answer specific community needs
    - SeaDataNet CDI/CSR (EU), AS/NZS (Australia/New Zealand)
  - Existing tools in other programming languages
    - Java:
      - GeoAPI / Apache SIS / GeoToolKit essentially;
      - GeoTools in a less extent;
    - Python: pygeometa

geometa – Project and Principle

- Object-Oriented R model (using **R6** classes)
- Model based on ISO / OGC schemas:
  - ISO 19115 (Dataset metadata),
  - ISO 19119 (Service metadata),
  - ISO 19136 (Geographic Markup Language - GML 3.2.1)
  - ISO 19110 (Feature Catalog),
  - ISO 19139 (XML Implementation)
- 1 schema element in the standard = 1 class in geometa

Metadata standards coverage

Standard	Title	Namespace	Coverage	Supported	Missing
ISO/TC211 19110:2005	Geographic Information - Methodology for feature cataloguing	GFC	100%	17	0
ISO/TC211 19115-1:2003	Geographic Information - Metadata	GMD	100%	132	0
ISO/TC211 19115-2:2009	Geographic Information - Metadata - Part 2: Extensions for imagery and gridded data	GMI	100%	40	0
ISO/TC211 19119:2005	Geographic Information - Service Metadata	SRV	37%	7	12
ISO/TC211 19139:2007	Geographic Metadata XML Schema	GMX	8%	5	61
ISO/TS 19103:2005	Geographic Common extensible markup language	GCO	100%	22	0
GML 3.2.1 (ISO 19136)	Geographic Markup Language	GML	37%	62	107
GML 3.2.1 Coverage (OGC GMLCOV)	OGC GML Coverage Implementation Schema	GMLCOV	100%	1	0
GML 3.3 Referenceable Grid (OGC GML)	OGC GML Referenceable Grid	GMLRGRID	100%	5	0

geometa – Recent developments

Thanks to financial support of R consortium

- Support of multi-language ISO/OGC metadata
- Add INSPIRE metadata validator
- Reach full coverage of standards:
  - ISO 19115-1 (Dataset metadata)
  - ISO 19115-2 (Extension for imagery and gridded datasets)
- Provide a (first) generic converter with other metadata standards
  - From/To EML (with EML and emld packages)
  - From NetCDF-CF conventions (with ncdf4 package)

geometa – How it works?

- All classes inherit from a superclass `ISOAbstractObject` that provides generic functions to deal with geometa objects
- Main functions inherited for all objects

encode(...)	Writes the geometa object in the equivalent XML (ISO 19139) metadata sheet
decode(xml = xml)	Reads a XML (ISO 19139) metadata element into a geometa object
validate()	Tests the compliance of the XML produced according to ISO 19139 schemas. By default, this method is triggered with *encode(...)*
save(file = file)	Saves the geometa object in the equivalent XML (ISO19139) as file

- Main function *readISO19139* to read geographic metadata from file or url

geometa – How it works - Basic metadata

- Class **ISOMetadata** (dataset metadata) the starting point...

```
#create ISOMetadata object
md = ISOMetadata$new()

#metadata identifier
md$setFileIdentifier("my-metadata-identifier")
#parent metadata identifier
md$setParentIdentifier("my-parent-metadata-identifier")
#charset
md$setCharacterSet("utf8")
#metadata language
md$setLanguage("eng")

#print (object summary)
md
```

geometa – How it works - Basic metadata

- Metadata sheet summary (print)
  - Allows to check the metadata in creation

```
<ISOMetadata>
....|-- fileIdentifier: my-metadata-identifier
....|-- language <ISOLanguage>: eng {English}
........|-- value: English
....|-- characterSet <ISOCharacterSet>: utf8 {8-bit variable size UCS
Transfer Format, based on ISO/IEC 10646}
........|-- value: utf8
....|-- parentIdentifier: my-parent-metadata-identifier
....|-- hierarchyLevel <ISOHierarchyLevel>: dataset {information
applies to the dataset}
........|-- value: dataset
```

geometa – How it works - codelists

- geometa manages all ISO/OGC standard codelists (loaded together with ISO/OGC schemas when loading the package)
- The list of available codelists can be obtained:

```
getISOCodelists()
```

- The elements of a codelist can be obtained with the method **$values()**

```
ISODateType$values(labels = TRUE)
```

- For *setter* methods, both codelist item or code (string) can be used:

```
md$setHierarchyLevel(ISOHierarchyLevel$new(value = "series"))
md$setHierarchyLevel("series")
```

geometa – How it works - multi-language

```
kwds <- ISOKeywords$new()
kwds$addKeyword(
    "keyword1",
    locales = list(
      EN = "keyword 1",
      FR = "mot-clé 1",
      ES = "palabra clave 1",
      AR = "1 الكلمة",
      RU = "ключевое слово 1",
      ZH = "关键词 1"
    )
)
```

- For all textual properties of an object, a `locales` argument can be used.

geometa – How it works - encode/save to ISO 19139

```
md$encode()   #or md$save("metadata.xml") to export to a file
```

- By default, encode() will test XML compliance with schemas. Results will appear as R message and comments in XML footer.

```
[geometa][WARN] Element '{http://www.isotc211.org/2005/gmd}dateStamp': This element is not expected. Expected is
one of ( {http://www.isotc211.org/2005/gmd}hierarchyLevel, {http://www.isotc211.org/2005/gmd}hierarchyLevelName,
{http://www.isotc211.org/2005/gmd}contact ) at line 8.
[geometa][WARN] Object 'ISOMetadata' is INVALID according to ISO 19139 XML schemas!
```

```
<gmd:MD_Metadata xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:gfc="http://www.isotc211.org/2005/gfc"
xmlns:gmd="http://www.isotc211.org/2005/gmd" xmlns:gmi="http://standards.iso.org/iso/19115/-2/gmi/1.0" xmlns:gmx=
"http://www.isotc211.org/2005/gmx" xmlns:gts="http://www.isotc211.org/2005/gts" xmlns:srv="
http://www.isotc211.org/2005/srv" xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:gmlcov="
http://www.opengis.net/gmlcov/1.0" xmlns:gmlrgrid="http://www.opengis.net/gml/3.3/rgrid" xmlns:xlink="
http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <gmd:characterSet>
    <gmd:MD_CharacterSetCode codeList="
    http://www.isotc211.org/2005/resources/Codelist/ML_gmxCodelists.xml#MD_CharacterSetCode" codeListValue="utf8"
    >utf8</gmd:MD_CharacterSetCode>
  </gmd:characterSet>
  <gmd:hierarchyLevel>
    <gmd:MD_ScopeCode codeList="http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MX_ScopeCode"
    codeListValue="dataset" codeSpace="ISOTC211/19115">dataset</gmd:MD_ScopeCode>
  </gmd:hierarchyLevel>
  <gmd:dateStamp>
    <gco:DateTime>2019-06-11T18:22:57</gco:DateTime>
  </gmd:dateStamp>
  <!--Metadata Creation date/time: 2019-07-08T20:24:34-->
  <!--ISO 19139 XML generated by geometa R package - Version 0.6-0-->
  <!--ISO 19139 XML compliance: NO-->
  <!--geometa R package information:    Contact: Emmanuel Blondel emmanuel.blondel1@gmail.com   URL:
  https://github.com/eblondel/geometa/wiki   BugReports: https://github.com/eblondel/geometa/issues-->
</gmd:MD_Metadata>
```

geometa – How it works - encode/save to ISO 19139 - INSPIRE

```
md$encode(inspire = TRUE)   #or md$save("metadata.xml", inspire = TRUE)
```

- With INSPIRE option, INSPIRE compliance results will be added as comments in XML footer.

```
[geometa][WARN] Element '{http://www.isotc211.org/2005/gmd}dateStamp': This element is not expected. Expected is
one of ( {http://www.isotc211.org/2005/gmd}hierarchyLevel, {http://www.isotc211.org/2005/gmd}hierarchyLevelName,
{http://www.isotc211.org/2005/gmd}contact ) at line 8.
[geometa][WARN] Object 'ISOMetadata' is INVALID according to ISO 19139 XML schemas!
[geometa][INFO] Sending metadata file to INSPIRE metadata validation web-service...
[geometa][INFO] INSPIRE metadata validation test done!
<gmd:MD_Metadata xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:gfc="http://www.isotc211.org/2005/gfc"
xmlns:gmd="http://www.isotc211.org/2005/gmd" xmlns:gmi="http://standards.iso.org/iso/19115/-2/gmi/1.0" xmlns:gmx=
"http://www.isotc211.org/2005/gmx" xmlns:gts="http://www.isotc211.org/2005/gts" xmlns:srv=
"http://www.isotc211.org/2005/srv" xmlns:gml="http://www.opengis.net/gml" xmlns:gmlcov=
"http://www.opengis.net/gmlcov/1.0" xmlns:gmlrgrid="http://www.opengis.net/gml/3.3/rgrid" xmlns:xlink=
"http://www.w3.org/1999/xlink" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <gmd:characterSet>
    <gmd:MD_CharacterSetCode codeList=
    "http://www.isotc211.org/2005/resources/Codelist/ML_gmxCodelists.xml#MD_CharacterSetCode" codeListValue=
    "utf8">utf8</gmd:MD_CharacterSetCode>
  </gmd:characterSet>
  <gmd:hierarchyLevel>
    <gmd:MD_ScopeCode codeList="http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MX_ScopeCode"
    codeListValue="dataset" codeSpace="ISOTC211/19115">dataset</gmd:MD_ScopeCode>
  </gmd:hierarchyLevel>
  <gmd:dateStamp>
    <gco:DateTime>2019-06-11T18:22:57</gco:DateTime>
  </gmd:dateStamp>
  <!--Metadata Creation date/time: 2019-07-09T21:41:00-->
  <!--ISO 19139 XML generated by geometa R package - Version 0.6-0-->
  <!--ISO 19139 XML compliance: NO-->
  <!--INSPIRE compliance: NO-->
  <!--INSPIRE completeness: 11.11%-->
  <!--INSPIRE Report:
  http://inspire-geoportal.ec.europa.eu/resources/sandbox/INSPIRE-8f32e98e-a281-11e9-8b10-0050563f01ec_20190709-21
  4134/datasets/1/resourceReport-->
  <!--geometa R package information:    Contact: Emmanuel Blondel emmanuel.blondel1@gmail.com   URL:
  https://github.com/eblondel/geometa/wiki   BugReports: https://github.com/eblondel/geometa/issues-->
</gmd:MD_Metadata>
```

geometa – How it works - More?

- Convert from / to other metadata standards *[EXPERIMENTAL]*
  - From / To EML (EML/emld packages)

```
#from geometa to emld
emld_obj = as(md, "emld")
```

```
#from emld to geometa
f <- system.file("extdata/example.xml", package="emld")
eml <- as_emld(f)
md_obj = as(emld, "ISOMetadata")
```

  - From NetCDF-CF - Climate & Forecast Conventions (ncdf4 package)

```
#from ncdf4 to geometa
nc =
ncdf4::nc_open("http://gsics.eumetsat.int/thredds/dodsC/DemoLevel1B25K
m/W_XX-EUMETSAT-Darmstadt,SURFACE+SATELLITE,METOPA+ASCAT_C_EUMP_201312
31231800_37368_eps_o_125_l1.nc")
md_cf = as(nc, "ISOMetadata")
```

geometa – How it works - Read an ISO 19139 file

Reading come interesting when we want to update metadata, local or fetched from a remote metadata catalogue:

```
#metadata example file
mdfile <- system.file("extdata/examples", "metadata.xml",
                      package = "geometa")

#read it in geometa
md <- readISO19139(mdfile)
```

geometa – Perspectives

- Consolidate converter for moving from one metadata standard to another
- Enrich conversion rules (“mappings”) liaising with communities:
  - With Ecological Metadata Language (EML)
  - With NetCDF-CF Conventions
- Provide functions to connect easily to web controlled vocabularies for easier metadata production
- Extend the coverage of native GML support to foster interoperability with OGC web-services through R.

ows4R – Project and Principle

- “OGC Web-Services for R”
- Objective: To provide an interface in R for using OGC web-services, and associated standards. These standards are designed to provide a common way to access and manage geographic (meta)data on the web, such as:
  - Catalogue Service for the Web (CSW) → geographic metadata
  - Web Feature Service (WFS) → vector data
  - Web Coverage Service (WCS) → raster data
  - etc.
- Analog to Python “OWSLib”
- Object-Oriented R model (using **R6** classes)

ows4R – Project and Principle

- OGC standards coverage

Standard	Description	Supported versions	Unsupported versions	Supported R bindings	Support
OGC Filter	Filter Encoding	`1.1.0`	`2.0`		ongoing
OGC Common	Web Service Common	`1.1,2.0`			ongoing
OGC CSW	Catalogue Service	`2.0.2`	`3.0.0`	geometa (ISO 19115 / 19119 / 19110 / 19139 XML)	ongoing / seeking sponsors
OGC WFS	Web Feature Service	`1.0.0,1.1.0,2.0.0`		sf (OGC Simple Feature)	ongoing
OGC WCS	Web Coverage Service	`1.1.0`, `1.1.1`, `2.0.1`	`1.0.0`	raster	Not yet released - under investigation / seek sponsors

ows4R – Metadata services

- Interact with a CSW- compliant metadata catalogue (eg GeoNetwork)

```
fao_csw <- CSWClient$new(
  url = "http://www.fao.org/geonetwork/srv/en/csw" ,
  serviceVersion = "2.0.2",
  logger = "INFO"
)
```

- Search metadata

```
cons <- CSWConstraint$new(cqlText = "dc:identifier like '%firms%'" )
q <- CSWQuery$new(constraint = cons)
records <- fao_csw$getRecords(
  query = q, outputSchema = "http://www.isotc211.org/2005/gmd" )
```

- Get metadata

```
record <- fao_csw$getRecordById("fao-species-map-tth", outputSchema =
"http://www.isotc211.org/2005/gmd")
```

ows4R – Metadata services

- Operations for metadata transactions

insertRecord(...)	Push a geometa object into a CSW catalogue
updateRecord(...)	Updates an existing ISO 19139 record on CSW with a new geometa object. Batch/Selective update based on filters is possible.
deleteRecord(...)	Deletes a record on CSW

ows4R – Data services

- Vector Data retrieval interacting with an OGC Web Feature Service (WFS)

```
fao_wfs <- WFSClient$new(
  url = "http://www.fao.org/figis/geoserver/species/wfs",
  serviceVersion = "1.0.0",
  logger = "INFO"
)
```

- List all feature types (GIS data “layers”)

```
fao_wfs$getFeatureTypes(pretty = TRUE)
```

- Outputs mapped with `sf` (Simple Features) package. Optional WFS vendor parameters given as arguments (eg CQL_FILTER)

```
tth = fao_wfs$getFeatures("species:SPECIES_DIST_TTH")
```

ows4R – Perspectives

- Support any OGC standard service not yet supported in R
- Priority list, depending on resources
  - **Web Coverage Service support** to manage grid data.
    Ongoing promising experiments for fetching multi-dimensional raster / grid arrays, with tests on GeoServer and Rasdaman WCS implementation, starting managing outputs with `raster` package (raster / stack objects).

    Objective: To offer a standard, reproducible and sustainable way to access and query raster/imagery data in R from the web

  - **WFS Transactional mode** (Push/Update/Delete spatial data through standard protocol)
  - CSW 3.0 support

geoflow initiative

- We can now manage geographic metadata with R, interacting with web metadata catalogues… but OGC standards are huge and quite… “indigeste” for newbies… This deserves some simplification...
- The geoflow initiative is an attempt to help data managers to manage their SDI in easy and reproducible way

- Project page: https://github.com/eblondel/geoflow
- Current development status:
  - Available Github. First release on CRAN planned for 2019
  - Ongoing applications with Food & Agriculture Organization of the United Nations (UN-FAO), the French IRD (UMR Marbec), and French INRA (UMR Dynafor / Zones Ateliers).

Food and Agriculture Organization of the United Nations

French National Research Institute for Sustainable Development
Institut de Recherche pour le Développement
FRANCE

marbec
marine biodiversity exploitation & conservation

INRA
SCIENCE & IMPACT

geoflow- Objectives

- Orchestrate
  - Upstream data processings (data qualification, spatial, statistics, etc.)
  - Metadata creation / publication / update
  - Dataset publication (upload, enabling of spatial data OGC services)
- Automate
  - Avoid using complex web forms and manual metadata editing
  - Avoid repetitive tasks: eg enter same contacts for multiple metadata sheets
  - Foster proper discovery of datasets over the web with automated referencing with controlled vocabularies (eg Taxonomy).
  - Set-up multiple entry points for data discovery & access from a mutualized (meta)data source
- Facilitate the implementation of a Data Management Plan (DMP)
  - Set of predefined actions
  - Possibility for data managers to plug their own tools
    - In-house data sources and repository (eg. PostgreSQL database)
    - In-house tools/APIs
- Foster FAIR Principles (Findable, Accessible, Interoperable, Reusable)

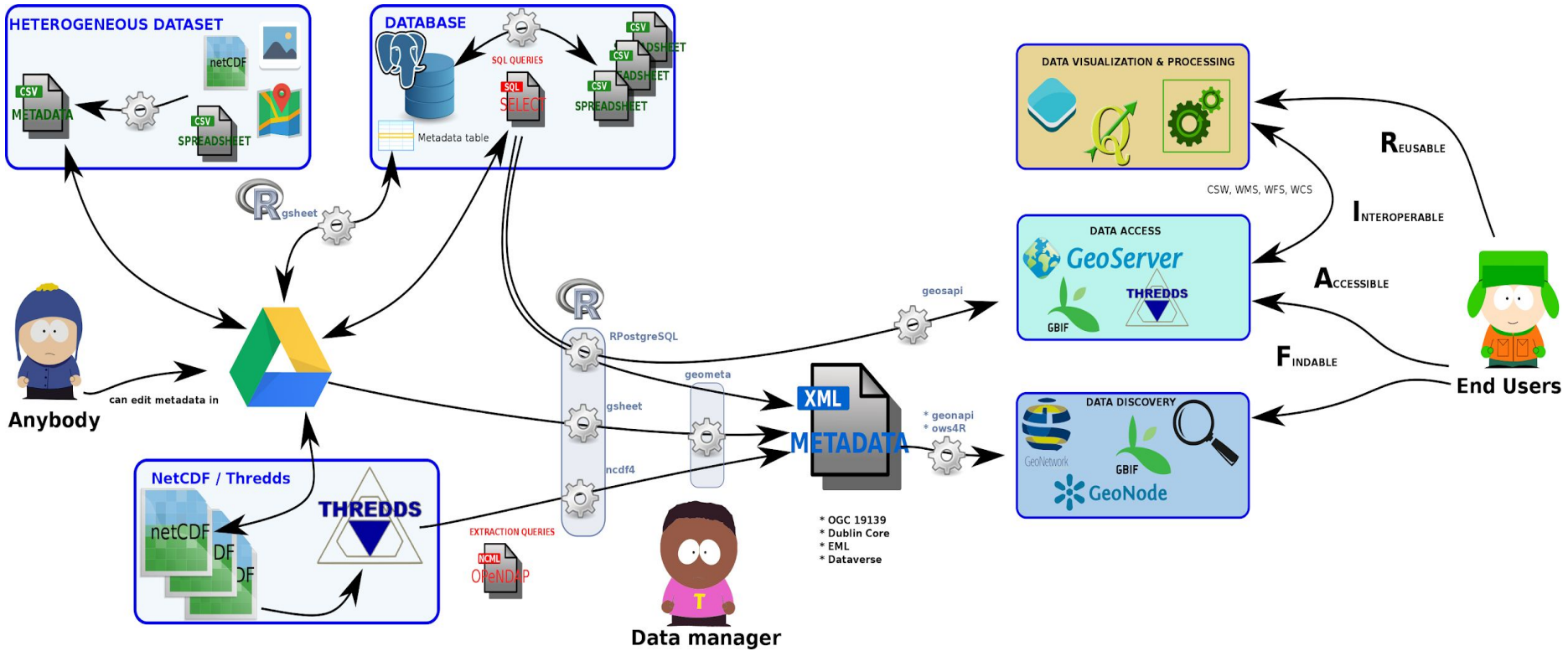
geoflow - How it works

- A simplified metadata model…
  - Two “tables”:
    - Dataset metadata (1 row = 1 dataset)
    - Contacts (*Directory*)
  - Contacts, Title, Abstract, Subjects/Keywords, spatial/temporal extent, etc
- Managed through various formats ...
  - Metadata: CSV, Excel, Google Sheets
  - Contacts: CSV, Excel, Google Sheets (+ LDAP on wishlist)
- Various web tools where to push (meta)data...
  - General tools: Zenodo (EU e-infrastructure), others on wishlist (Dataverse, CKAN)
  - Specific tools:
    - Spatialized (meta)data: GeoNetwork, GeoServer
    - Others on wishlist (eg GBIF for biodiversity)

geoflow - How it works

- One configuration file (json) where we declare:
  - **(Meta)data sources**
    - Main “entities” (1 entity = 1 dataset = 1 dataset metadata)
    - Contacts
  - **Target tools** e.g zenodo, geonetwork, geoserver, etc.
  - **Actions**:
    - Create a deposit on Zenodo with DOI attribution
    - Create an ISO/OGC metadata
    - Publish ISO/OGC metadata sheet (Geonetwork or other)
    - Publish a shapefile on Geoserver
    - Etc…
- A single R code line: `executeWorkflow("config.json")`

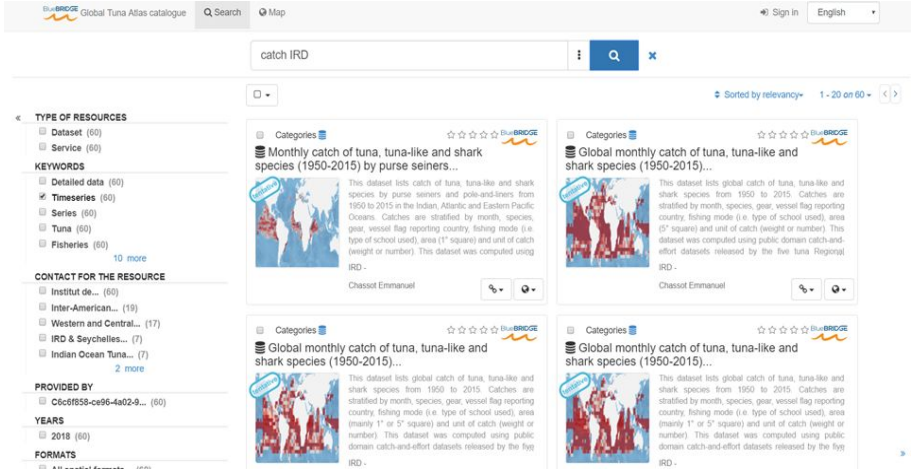
geoflow - In summary

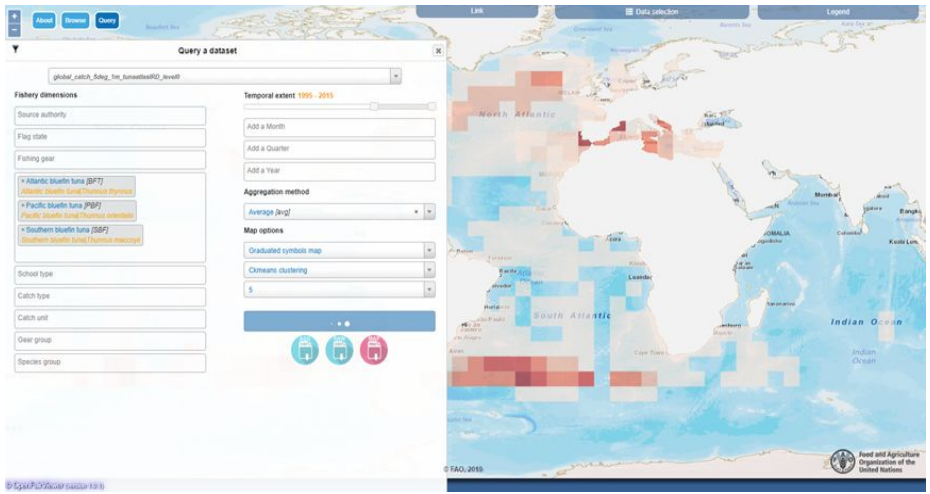


geoflow - Examples of SDI managed with R

- Fisheries Global Information System - FIGIS (FAO)

- Global Tuna Atlas (FAO / IRD / BlueBridge)





Thanks for your attention