Reproducible science, cloud-based Earth observation data processing, openEO

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openEO

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What does *I am a data scientist* mean?

I:

- have some domain knowledge (environmental, hydrology, RS)
- know some about spatial statistics
- communicate code

What does *I communicate code* mean?

I:

- write code (quite a lot)
- share code, mostly as R packages, but also in blogs and tweets
- engage in discussions concerning code (GH issues, SO, lists)
- actively engage with user and developer communities

I have a (meta-)scientific interest in what *reproducible geosciences* means.

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How does data science work?

To get things done, data scientists use languages, e.g. python, R, javascript or Julia, ... that share the following properties:

- they run everywhere, rather easily
- you can express problems in compact, human-readable and reproducible scripts
- unnecessary technical details (file format details, http calls, json/xml) are hidden
- code condensation is possible thanks to a package system, which also runs everywhere
- the language and package system are open source
- package systems resemble ecosystems
- analyses are shared/reproduced through Jupyter notebooks or R-markdown files.

What is reproducibility?

Here: if you give me your data and software, can I repeat your computations and get identical outcomes?

Why is this good?

- We want: *decisions and actions that are informed by Earth observation information and services* (abridged GEO vision)
- Information is derived from data through *analysis*, which involves computation
- Trust in information comes from a shared understanding of what the data are, how we analyse, and which computations were involved
- Computations happen with software
- When do we trust software?
  1. when a lot of people use it,
  2. when we can verify it by running tests, comparisons and benchmarks,
  3. when we can verify (and potentially improve) the source code.

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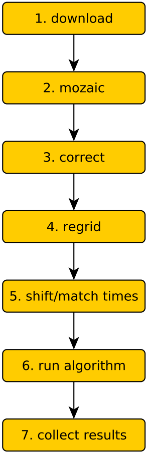
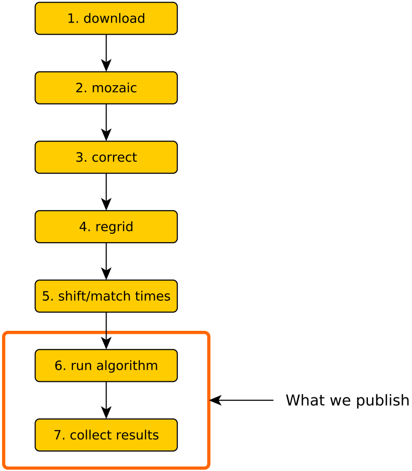
Current Earth Observation Research:



Current Earth Observation Research:



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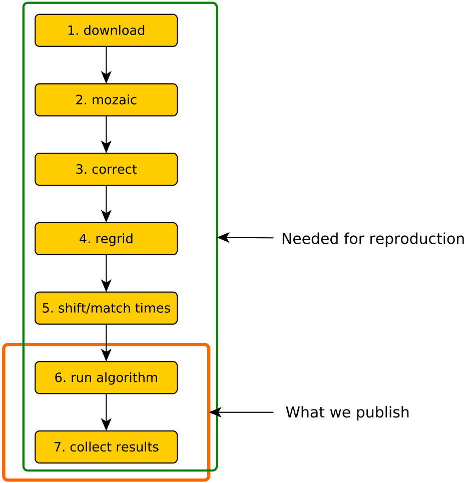
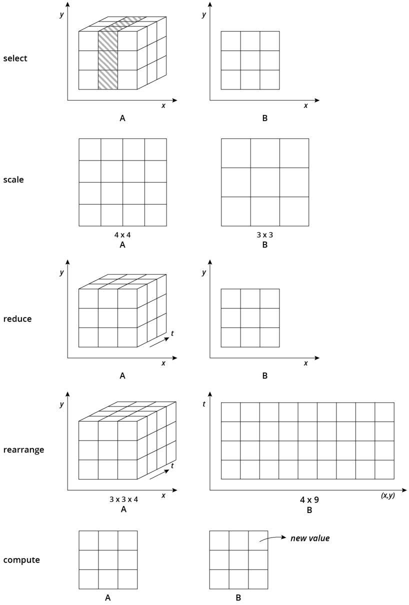
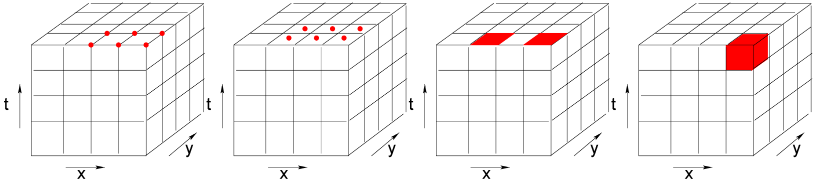


How do we *name* array operations



Is a pixel a point or an area?



M. Lu et al, Multidimensional Arrays for Analysing Geoscientific Data ISPRS Int. J. Geo-Inf. 2018, 7(8), 313;

https://doi.org/10.3390/ijgi7080313

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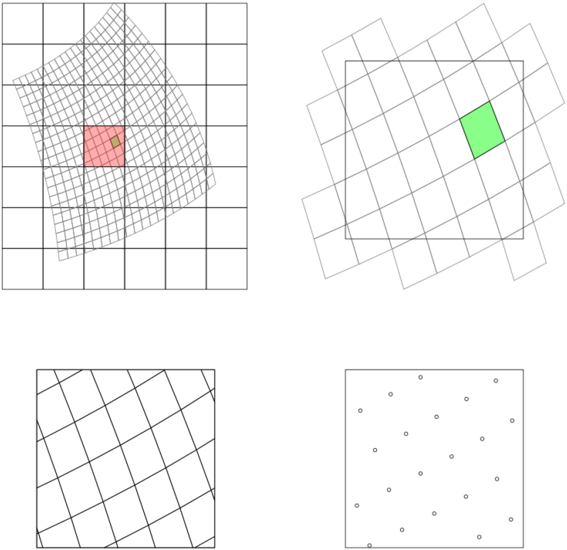
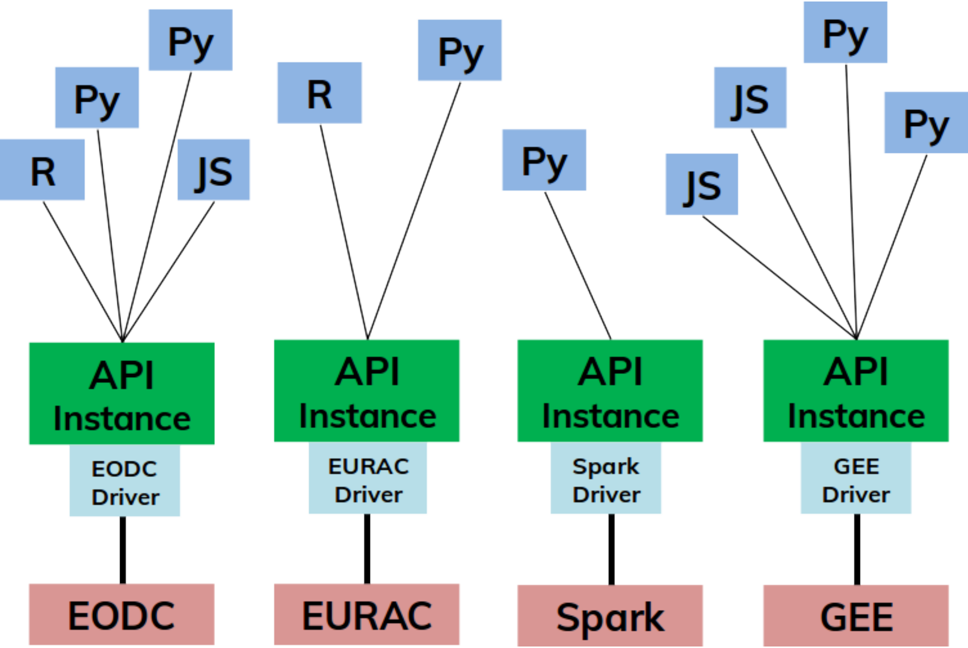


openEO

- H2020, Oct 2017-2020,
- http://openeo.org/
- openEO develops an open API to connect R, python and javascript clients to big Earth observation cloud back-ends in a simple and unified way.



R
Py
Py
JS

API Instance

EODC Driver

EODC

R
Py

API Instance

EURAC Driver

EURAC

Py

API Instance

Spark Driver

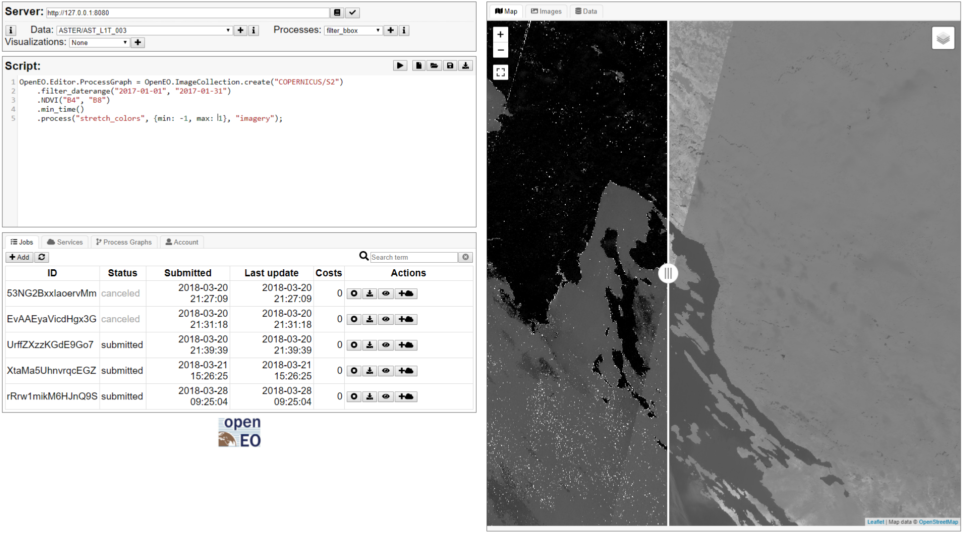
Spark

JS
JS
Py
Py

API Instance

GEE Driver

GEE



Server: http://127.0.0.1:8080

Data: ASTER/AST_L1T_003

Processes: filter_bbox

Visualizations: None

Script:

```
OpenEO.Editor.ProcessGraph = OpenEO.ImageCollection.create("COPERNICUS/S2")
    .filter_daterange("2017-01-01", "2017-01-31")
    .NDVI("B4", "B8")
    .min_time()
    .process("stretch_colors", {min: -1, max: 1}, "imagery");
```

ID	Status	Submitted	Last update	Costs	Actions
53NG2BxxlaoervMm	canceled	2018-03-20 21:27:09	2018-03-20 21:27:09	0	
EvAAEyaVicdHgx3G	canceled	2018-03-20 21:31:18	2018-03-20 21:31:18	0	
UrffZXzzKGdE9Go7	submitted	2018-03-20 21:39:39	2018-03-20 21:39:39	0	
XtaMa5UhnvrqcEGZ	submitted	2018-03-21 15:26:25	2018-03-21 15:26:25	0	
rRrw1mikM6HJnQ9S	submitted	2018-03-28 09:25:04	2018-03-28 09:25:04	0	

```
{ "process_id":"min_time",
  "args":{
    "imagery":{
      "process_id":"/user/custom_ndvi",
      "args":{
        "imagery":{
          "process_id":"filter_daterange",
          "args":{
            "imagery":{
              "process_id":"filter_bbox",
              "args":{
                "imagery":{
                  "product_id":"S2_L2A_T32TPS_20M"
                },
                "left":652000,
                "right":672000,
                "top":5161000,
                "bottom":5181000,
                "srs":"EPSG:32632"
              }
            },
            "from":"2017-01-01",
            "to":"2017-01-31"
          }
        },
        "red":"B04",
        "nir":"B8A"
      }
    }
  }
}
```

Cube view

File-agnostic access to EO imagery through a data cube view boosts usability of EO data.

In openEO:

- spatial dimensions are complemented with other dimensions such as the temporal or spectral dimensions
- researchers can directly filter, aggregate, or map functions over dimensions of a user-defined cube without being concerned about how the data in the processing platform is organised (granules, collections, coverages, ...)
- raster and vector data cubes are integrated.

Proof of Concept

The Month 6 (April 2018) proof of concept involved:

- coupling 3 clients (Python, R, JavaScript web-editor: figure left) to 7 back-ends (Sentinel Hub, GRASS GIS, EODC OpenStack, WCPS, Python GeoPySpark / GeoTrellis, Google Earth Engine, R) for
- 3 use-cases with band indexes, time series, aggregation over polygons, and user-defined (Python) functions
- source code and API docs on GitHub
- P.o.C. demo videos on the project web site

Why don't we build upon existing geo-standards?

- which standards?
- ...
- we do use non-geo standards where appropriate:
  - OpenAPI / swagger 3.0, allowing auto code generation for new clients
  - OAuth2 for user authentication
- no useful standards exist for describing (discovering, processing, publishing) image collection / dataset series;
- together with the GEE team, we do engage in describing these (in the space-time asset catalogue, STAC)

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Upcoming challenges

- MANY!!
- A big one: UDFs (user-defined functions): how can I have my back-end execute my arbitrary (python, R) function on selected imagery?
- validating (verifying) back-ends against each other
- combining several back-ends
- User adoption: how/when will users start to adopt this (clients AND servers need to work, be useable, and be affordable!)

Towards a *results-oriented GEO*?

- provide (develop, share access to) compute nodes where big EO data can be *sensibly* analysed
- sensibly:
  - not by tile, but by image collection
  - providing a user-defined cube view
- implement simple methods (open source, or otherwise open API) to compute there
- develop benchmarks showing that these compute nodes produce the same results given the same queries (openEO)
- develop best practice executable documents (e.g. Jupyter notebooks) showing how one could use this software/service infrastructure to answer questions (openEO)
- create a sustainable ecosystem of users
- ... by creating a "pit of success"?