Spatial Databases: PostGIS

Option GIS-Python

hes·so business.

Jean-Paul Calbimonte

School of Management

Bachelor of Science HES-SO (BSc) in Business Information Technology

swissuniversities

> Before we start ...

install QGIS: useful for visualizing and connecting with PostGIS

https://www.qgis.org

> PostGIS

What is PostGIS?

- Extension to the PostgreSQL object-relational database
- Allows GIS (Geographic Information Systems) objects to be stored in the database.
- Support for R-Tree spatial indexes.
- Functions for analysis and processing of GIS objects.

> PostGIS geometry types

Hes·so VALAIS WALLIS

Geometries in WKT (well known text):

- `POINT(0 0)`
- `LINESTRING(0 0,1 1,1 2)`
- `POLYGON((0 0,4 0,4 4,0 4,0 0),`
  `(1 1, 2 1, 2 2, 1 2,1 1))`
- `MULTIPOINT((0 0),(1 2))`
- `MULTILINESTRING((0 0,1 1,1 2),(2 3,3 2,5 4))`
- `MULTIPOLYGON(((0 0,4 0,4 4,0 4,0 0),(1 1,2 1,2 2,1 2,1 1)),`
  `((-1 -1,-1 -2,-2 -2,-2 -1,-1 -1)))`
- `GEOMETRYCOLLECTION(POINT(2 3),`
  `LINESTRING(2 3,3 4))`

Essentially same types as in Python/shapely

> Install Postgis: options

- Option 1: Install locally

- Option2: Install on docker

> Option1: Install PostgreSQL locally

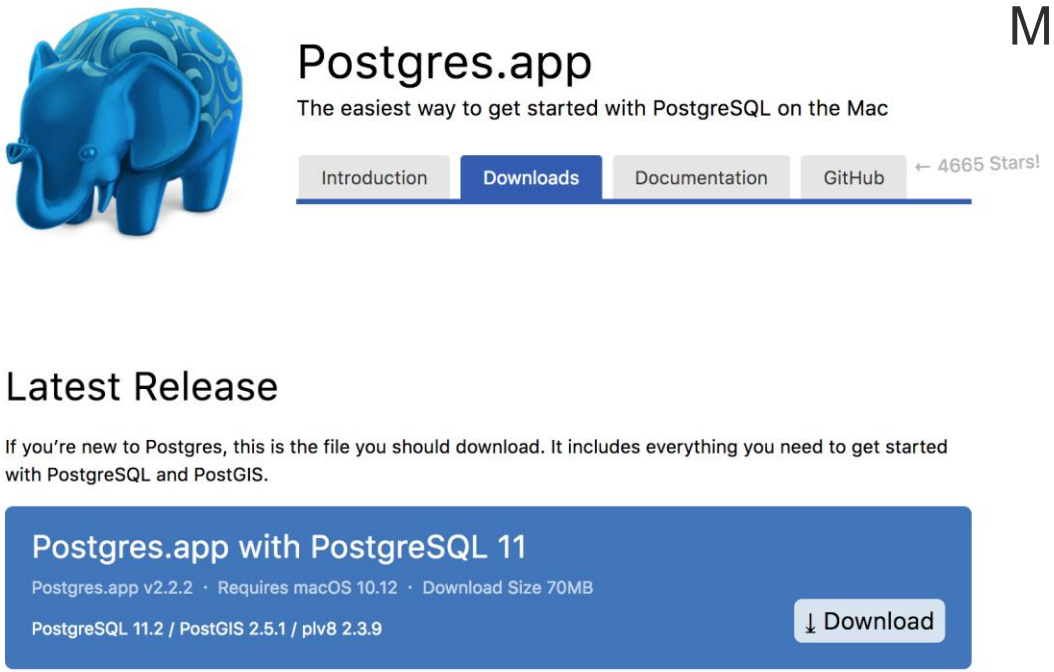
Windows:

https://www.postgresql.org/download/windows/

Mac:

http://postgresapp.com/

https://www.postgresql.org/download/macosx/



> Option 1: Install PostGIS locally

https://postgis.net/install/

PostGIS is an optional extension in PostgreSQL

To enable it enter into a **`psql`** console:

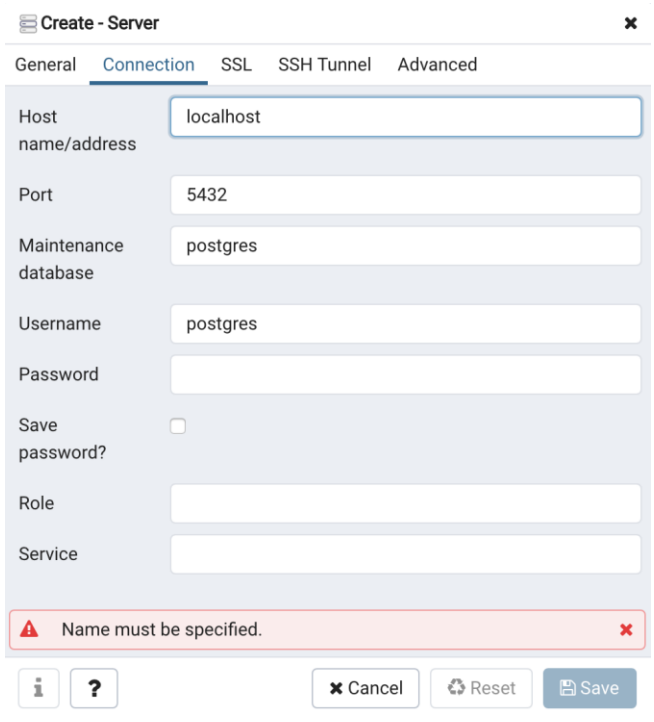
```
-- Enable PostGIS (includes raster)
CREATE EXTENSION postgis;

-- Enable Topology
CREATE EXTENSION postgis_topology;
```

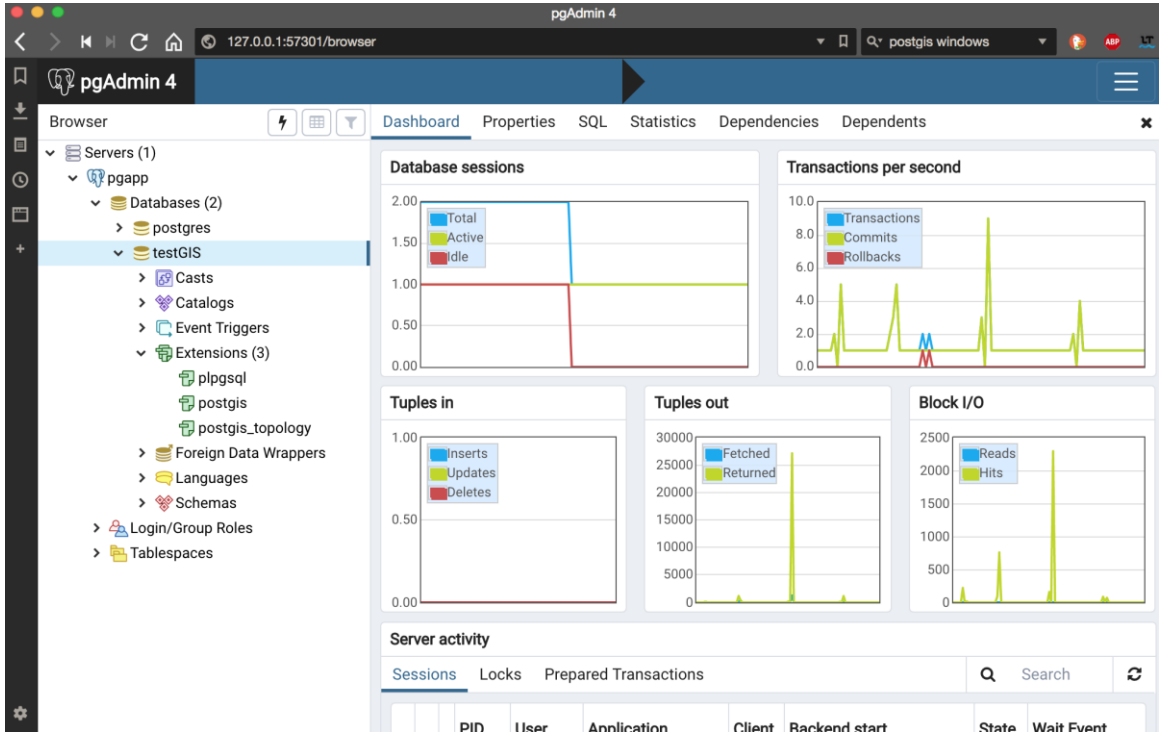
Other PostGIS extensions can be added if needed (e.g. 3D etc.)

> Option 1: Install pgAdmin locally

https://www.pgadmin.org

pgAdmin is a tool for managing PostgreSQL databases

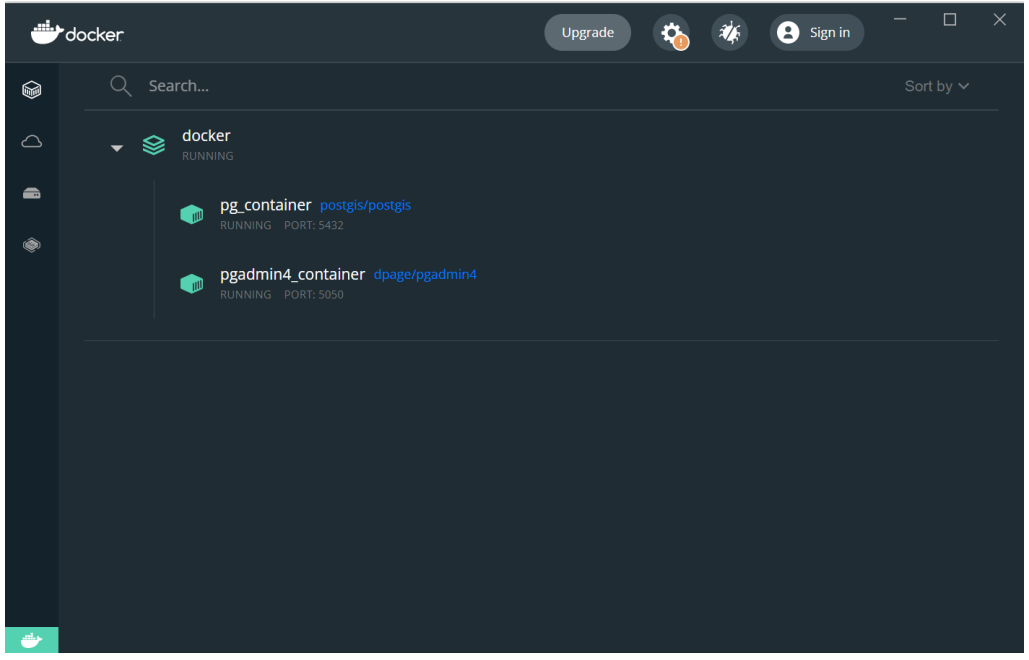




connect to your local PostgreSQL installation

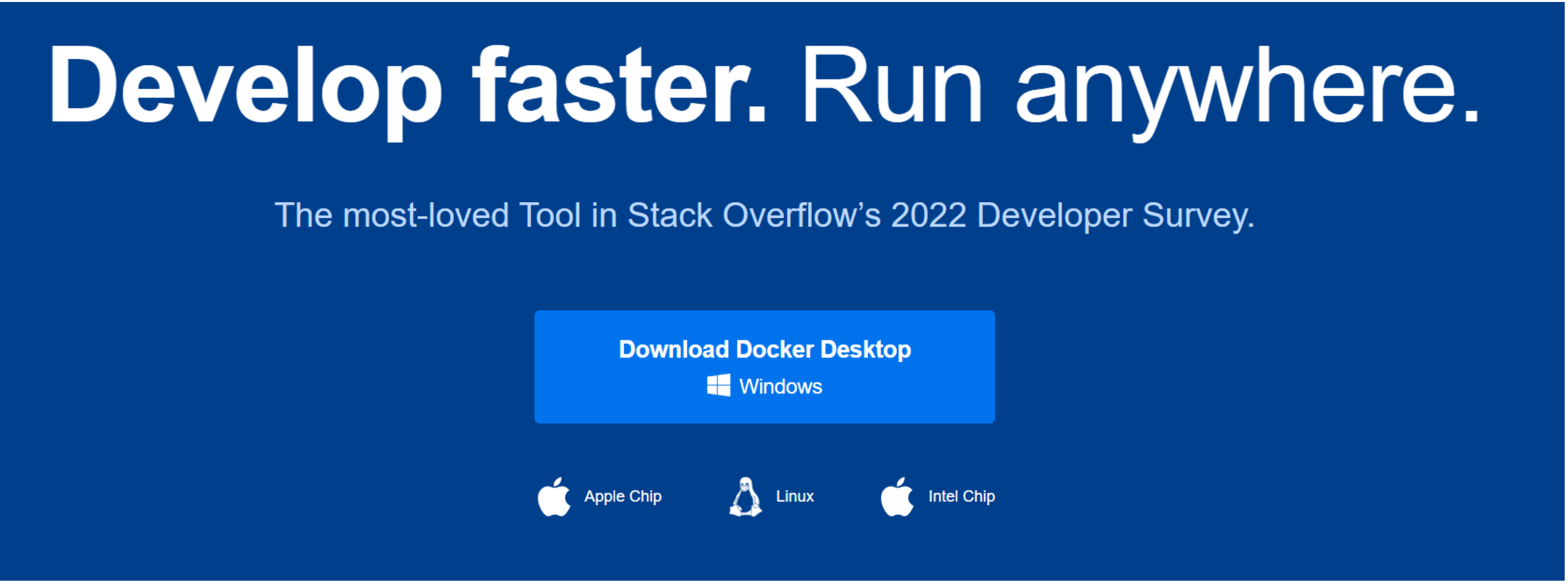
> Option 2: Install on docker

Or don’t install anything and use docker



>

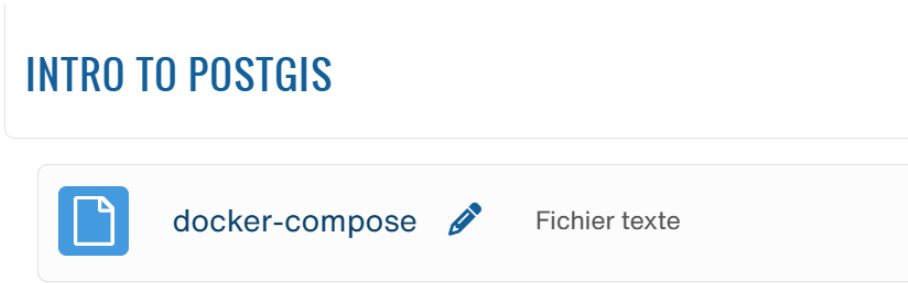
https://www.docker.com/



Install docker desktop

> PostGIS with docker

Download the **docker-compose.yml** file from Cyberlearn in a folder in your computer (for example a folder named postgis)



> PostGIS: Use docker compose

```yaml
version: '3.8'
services:
  db:
    container_name: pg_container
    image: postgis/postgis
    restart: always
    environment:
      POSTGRES_USER: root
      POSTGRES_PASSWORD: root
      POSTGRES_DB: test_db
    ports:
      - "5432:5432"
  pgadmin:
    container_name: pgadmin4_container
    image: dpage/pgadmin4
    restart: always
    environment:
      PGADMIN_DEFAULT_EMAIL: admin@admin.com
      PGADMIN_DEFAULT_PASSWORD: root
    ports:
      - "5050:80"
```

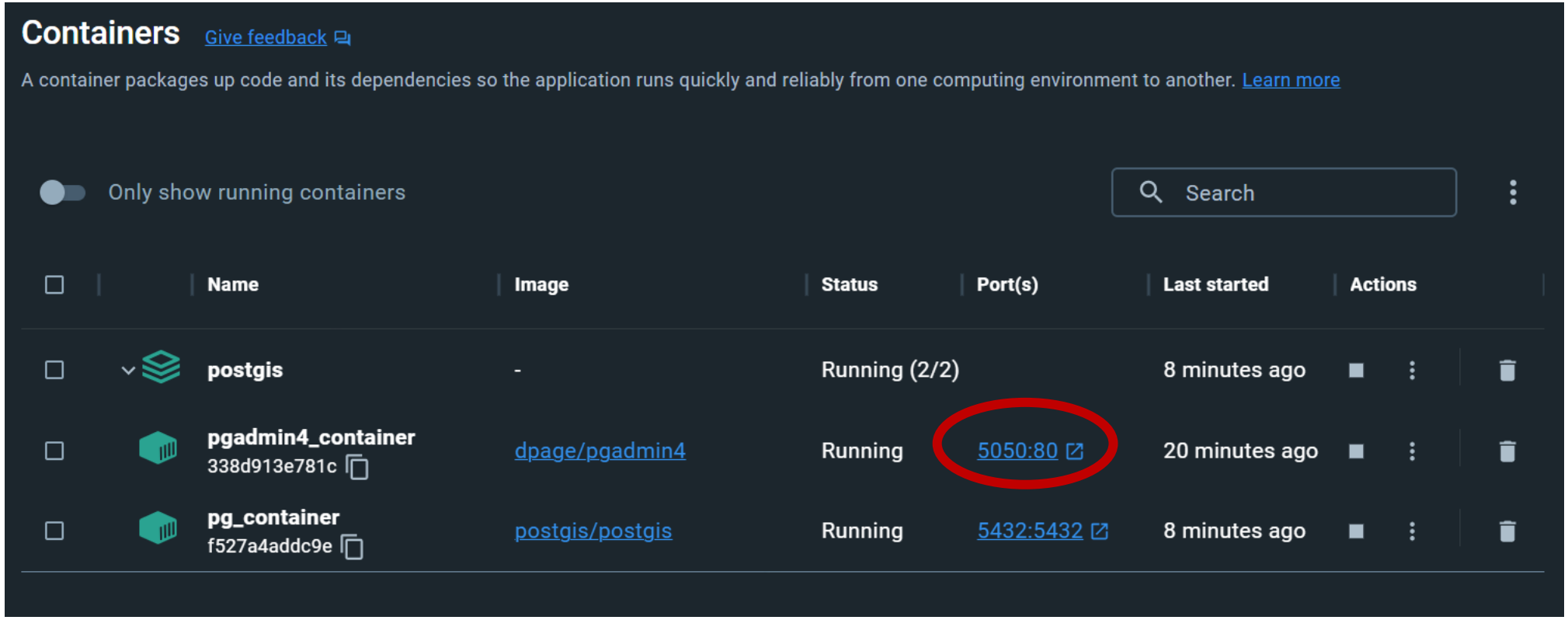
Now open a terminal in that folder and type:

```
>docker compose up
```

```
C:\Users\jpcik\git\postgis>docker compose up
[+] Running 0/18
 - db Pulling                                                                    3.0s
   - 3f9582a2cbe7 Pulling fs layer                                               0.6s
   - 0d9d08fc1a1a Pulling fs layer                                               0.6s
[+] Running 0/32b Pulling fs layer                                               0.6s
 - db Pulling                                                                    3.1s
   - 3f9582a2cbe7 Downloading [>                                ]  327.7kB/...    0.7s
   - 0d9d08fc1a1a Downloading [>                                ]   44.3kB/...    0.7s
```

> Running docker

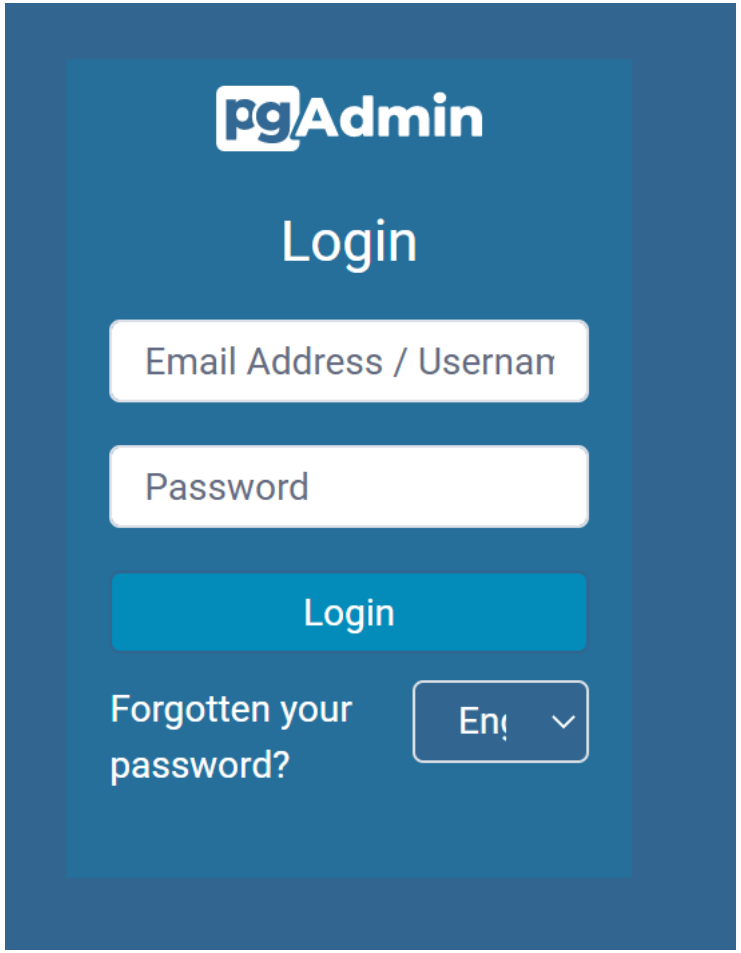
Now you should have both postgres/postgis (the database) and PgAdmin (the admin tool) running



Click here to open the Admin tool pgAdmin

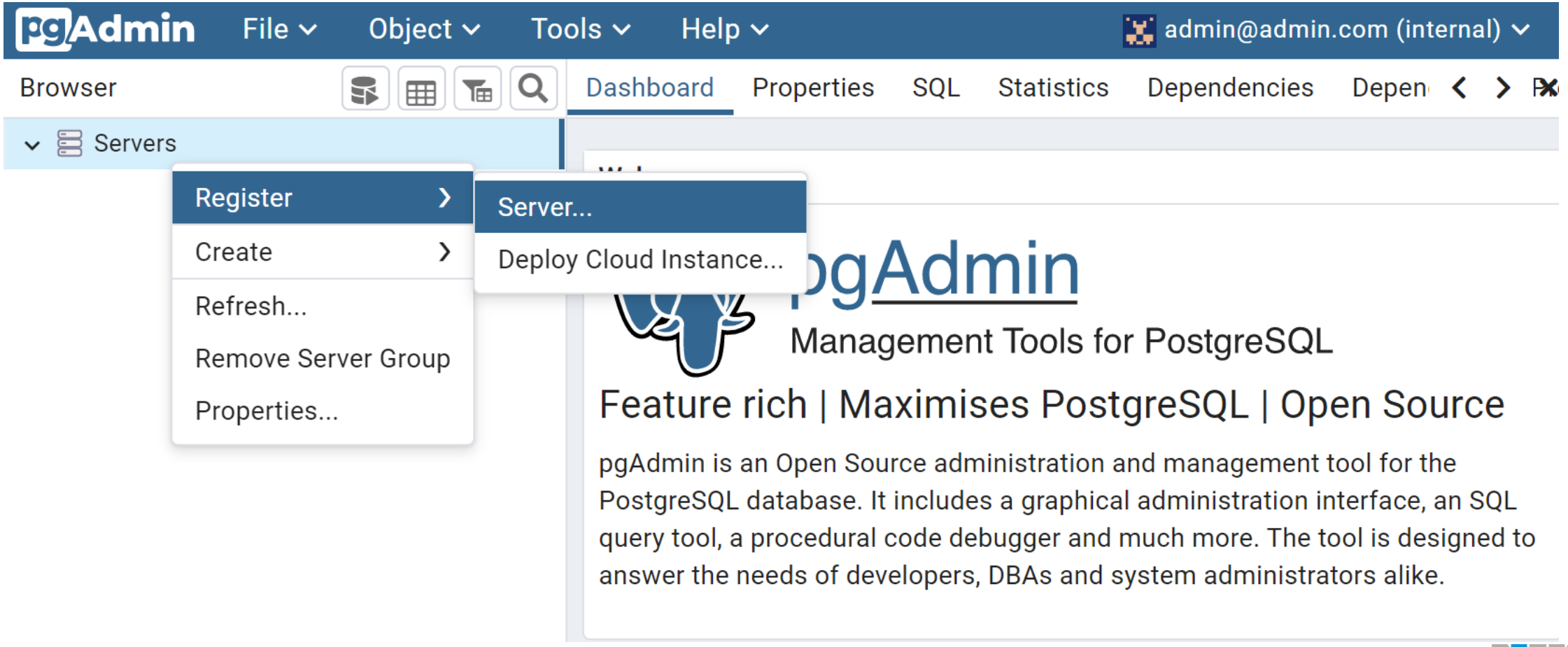
> pgAdmin

You can login with admin@admin.com, and password ‘root’



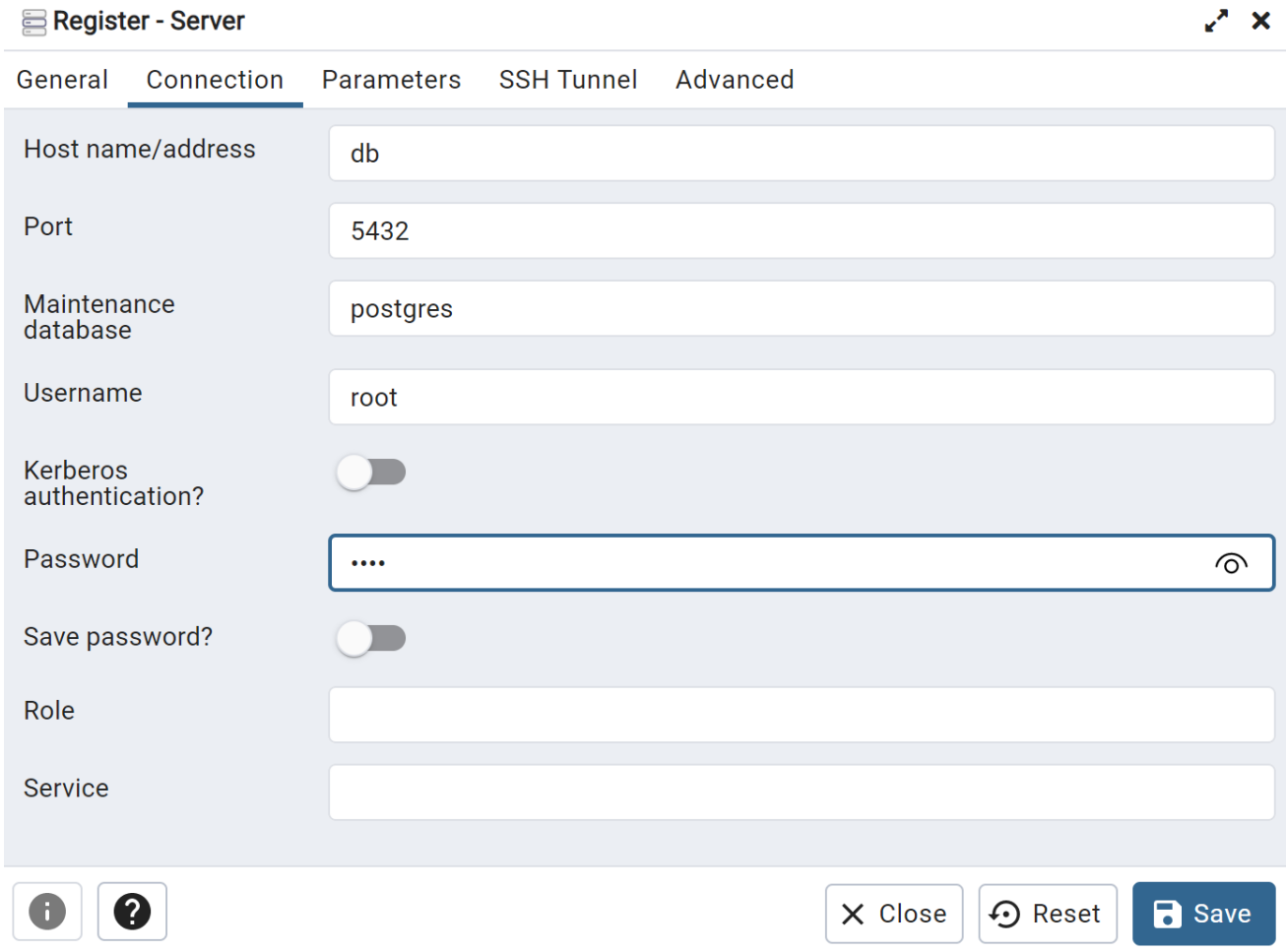
> pgAdmin

You can register a new server



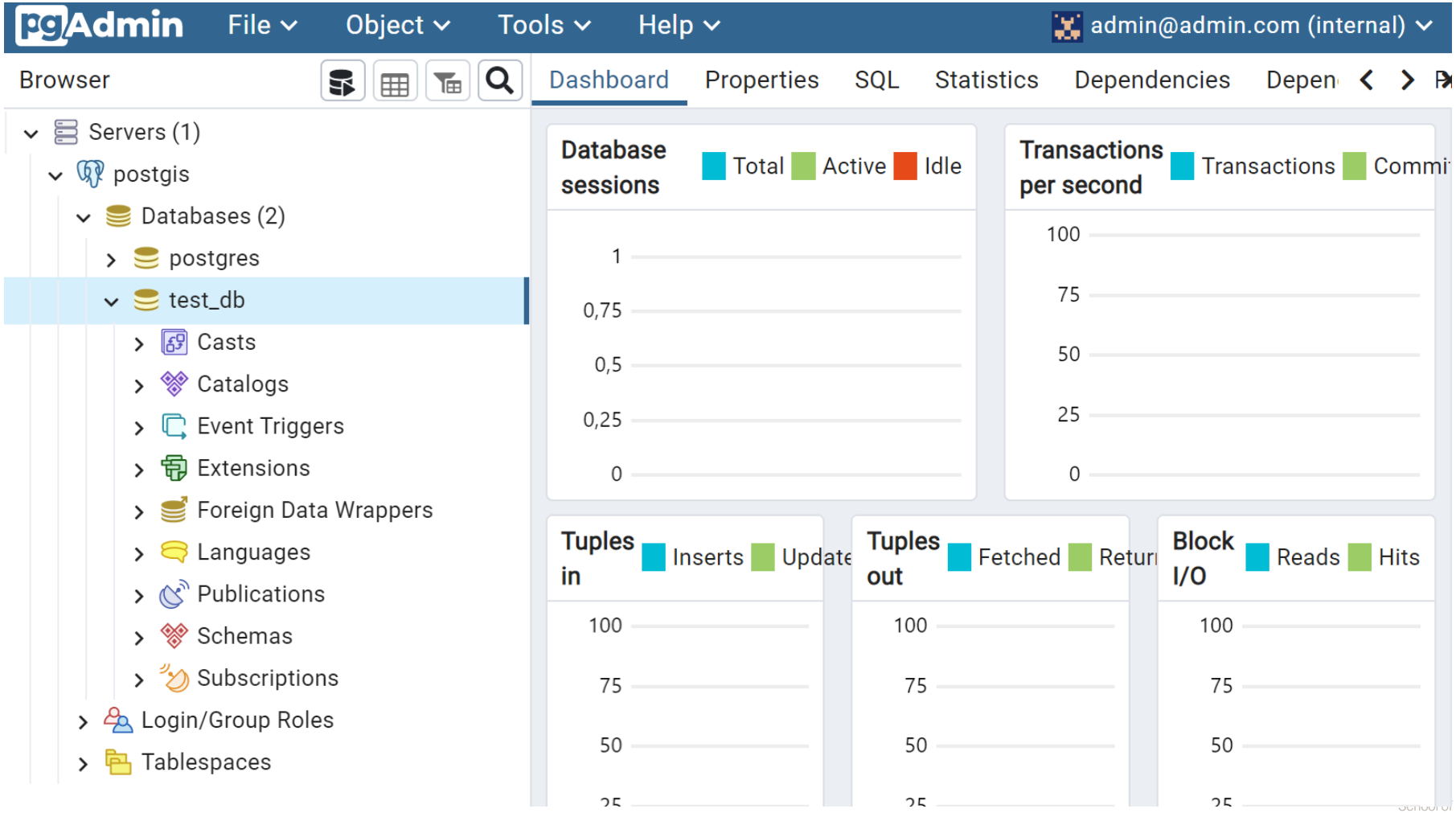
> pgAdmin

You may use these parameters and save:



> pgAdmin

And you are ready to start.

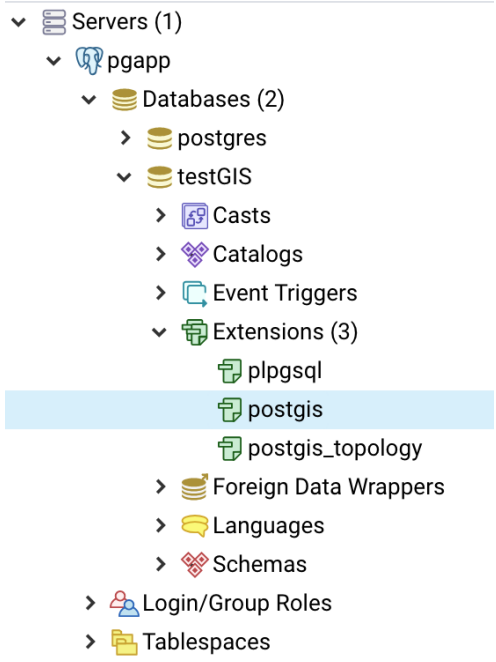


> PostGIS: first steps

In the query editor ⚡ check if installed, and version:

```
SELECT postgis_full_version();
```

```
POSTGIS="2.4.6 r17068" PGSQL="100" GEOS="3.6.3-CAPI-1.10.3 80c13047" PROJ…
```



extensions also visible in the sidebar

> PostGIS geometries

Create basic geometries:

```
CREATE TABLE geometries (name varchar, geom geometry);
```

```
INSERT INTO geometries VALUES
  ('Point', 'POINT(0 0)'),
  ('Linestring', 'LINESTRING(0 0, 1 1, 2 1, 2 2)'),
  ('Polygon', 'POLYGON((0 0, 1 0, 1 1, 0 1, 0 0))'),
  ('PolygonWithHole', 'POLYGON((0 0, 10 0, 10 10, 0 10, 0 0),
                               (1 1, 1 2, 2 2, 2 1, 1 1))'),
  ('Collection', 'GEOMETRYCOLLECTION(POINT(2 0),
                                     POLYGON((0 0, 1 0, 1 1, 0 1, 0 0)))');
```

```
SELECT name, ST_GeometryType(geom), ST_NDims(geom),
       ST_SRID(geom), ST_NumGeometries(geom)
FROM geometries;
```

"Point"	"ST_Point"	2	0	1
"Linestring"	"ST_LineString"	2	0	1
"Polygon"	"ST_Polygon"	2	0	1
"PolygonWithHole"	"ST_Polygon"	2	0	1
"Collection"	"ST_GeometryCollection"	2	0	2

> Point & LineStrings

Point

```
SELECT ST_X(geom), ST_Y(geom), ST_asText(geom)
FROM geometries
WHERE name = 'Point';
```

```
"0"    "0"    "POINT(0 0)"
```

LineString

```
SELECT ST_Length(geom), ST_Npoints(geom)
FROM geometries
WHERE name = 'Linestring';
```

```
"3.41421356237309"    4
```

> Polygons

```
SELECT name, ST_Area(geom),
       ST_NRings(geom),
       ST_AsText(ST_InteriorRingN(geom,1)),
       ST_AsText(ST_ExteriorRing(geom))
FROM geometries
WHERE name LIKE 'Polygon%';
```

```
"Polygon"          "1"   1    "LINESTRING(0 0,1 0,1 1,0 1,0 0)"
"PolygonWithHole"  "99"  2    "LINESTRING(1 1,1 2,2 2,2 1,1 1)"    "LINESTRING(0 0,10 0,10 10,0 10,0 0)"
```

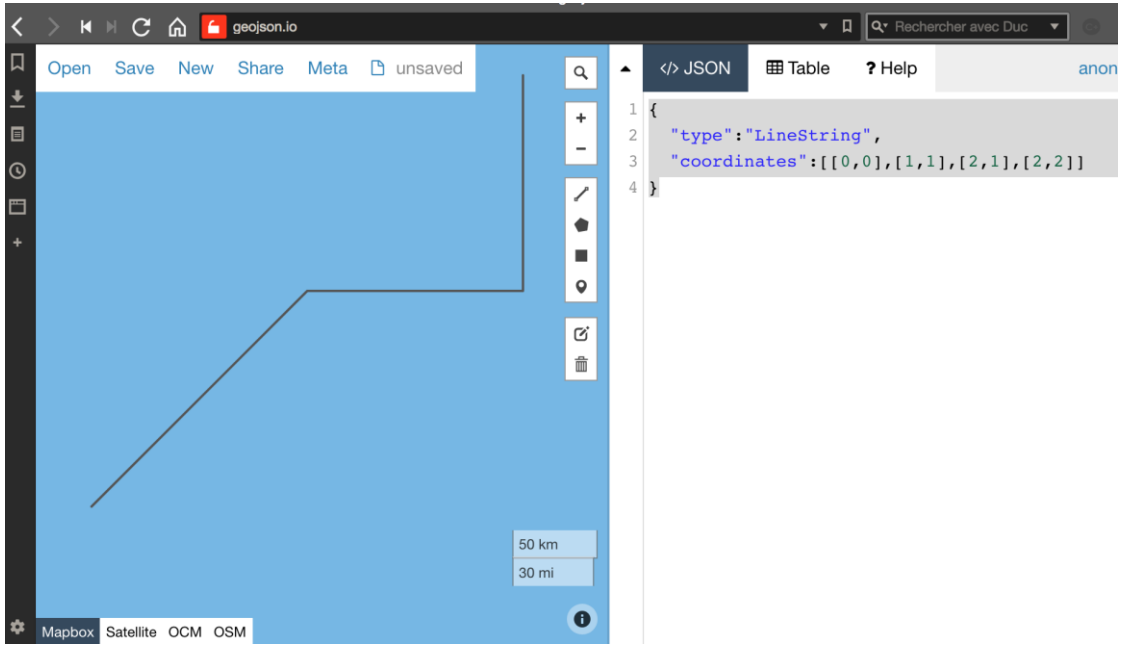
> Conversion functions

- ST_AsText: Returns the Well-Known Text (WKT) representation of the geometry/geography without SRID metadata.
- ST_AsBinary: Returns the Well-Known Binary (WKB) representation of the geometry/geography without SRID meta data.
- ST_EndPoint: Returns the last point of a LINESTRING geometry as a POINT.
- ST_AsEWKB: Returns the Well-Known Binary (WKB) representation of the geometry with SRID meta data.
- ST_AsEWKT: Returns the Well-Known Text (WKT) representation of the geometry with SRID meta data.
- ST_AsGeoJSON: Returns the geometry as a GeoJSON element.
- ST_AsGML: Returns the geometry as a GML version 2 or 3 element.
- ST_AsKML: Returns the geometry as a KML element. Several variants. Default version=2, default precision=15.
- ST_AsSVG: Returns a Geometry in SVG path data given a geometry or geography object.

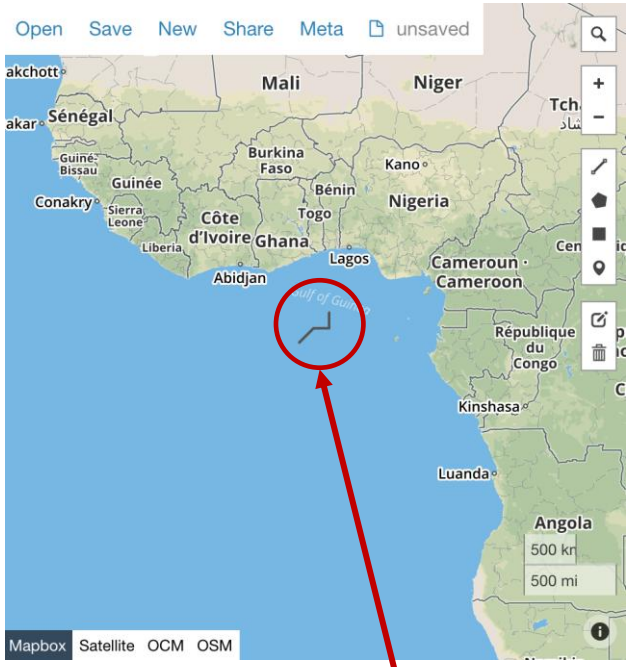
> Formats: GeoJSON

```
SELECT ST_AsGeoJSON(geom)  FROM geometries
WHERE name = 'Linestring';
```

```
{
 "type":"LineString",
  "coordinates":[[0,0],[1,1],[2,1],[2,2]]
}
```



visualize in geojson.io

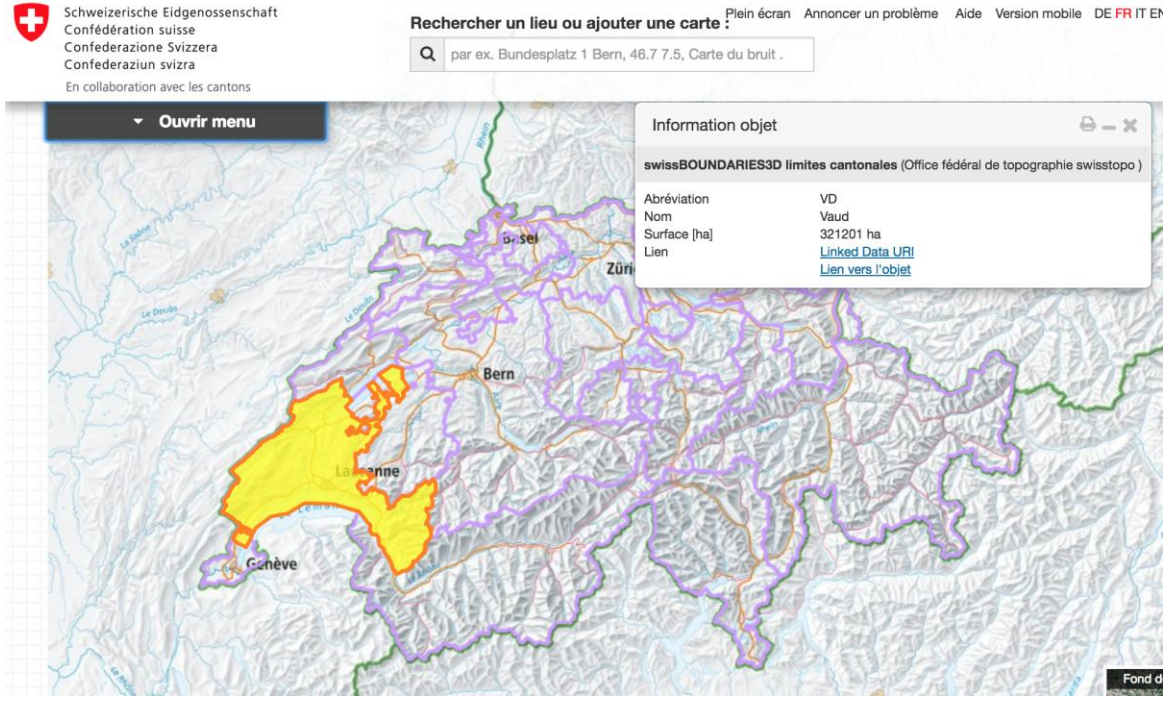


where in the world is this linestring?

> Loading Shapefiles

Load shapefile as a Table with spatial objects in it

https://map.geo.admin.ch/ Lots of official Swiss maps

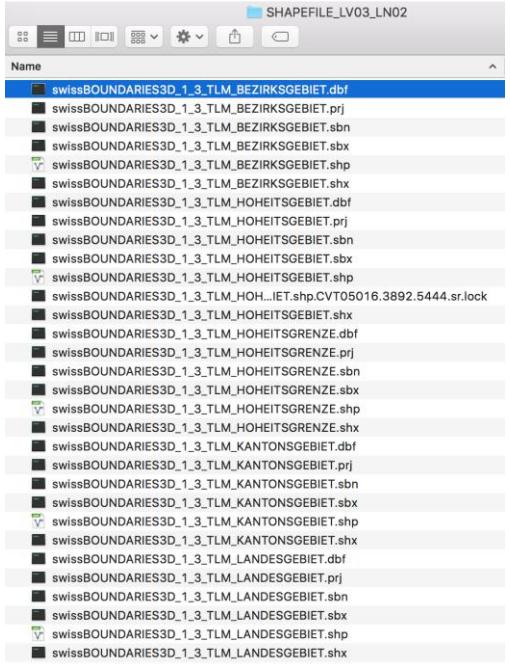


swissBOUNDARIES3D:
Swiss limits

http://data.geo.admin.ch/ch.swisstopo.swissboundaries3d-kanton-flaeche.fill/data.zip

> Loading Shapefiles

Lots of files inside the shapefile zip:



5 different layers:

borders (multi lines)

	Géométrie	Description
TLM_HOHEITSGRENZE	Polyligne	Limites administratives (frontières nationale, cantonale, de district, communale)
TLM_HOHEITSGEBIET	Polygone	Unités administratives de base (communes)
TLM_BEZIRKSGEBIET	Polygone	Territoires des districts
TLM_KANTONSGEBIET	Polygone	Territoires des cantons
TLM_LANDESGEBIET	Polygone	Territoires des pays

municipality polygons

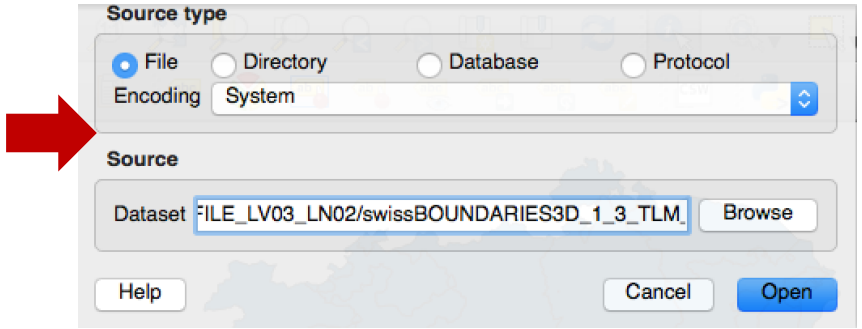
districts polygons

canton polygons

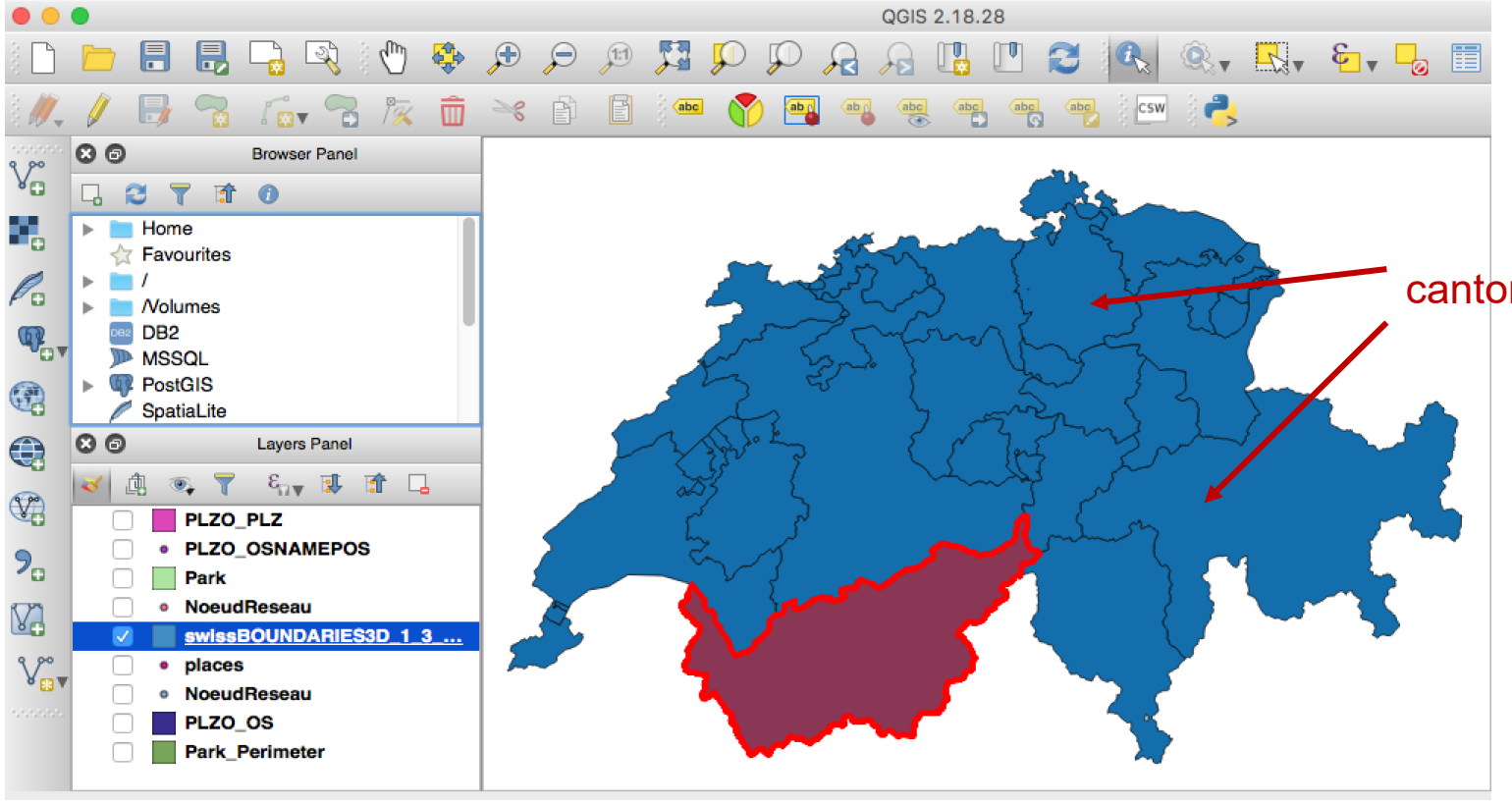
country polygons

> Loading Shapefiles

Open one shapefile layer in QGIS

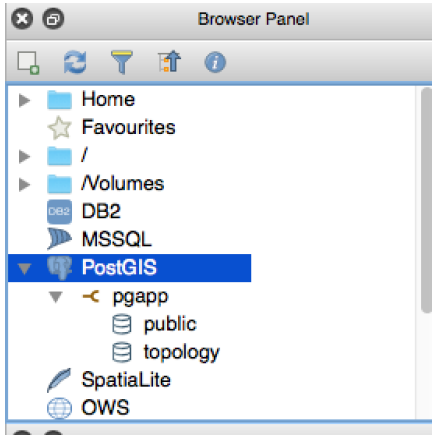


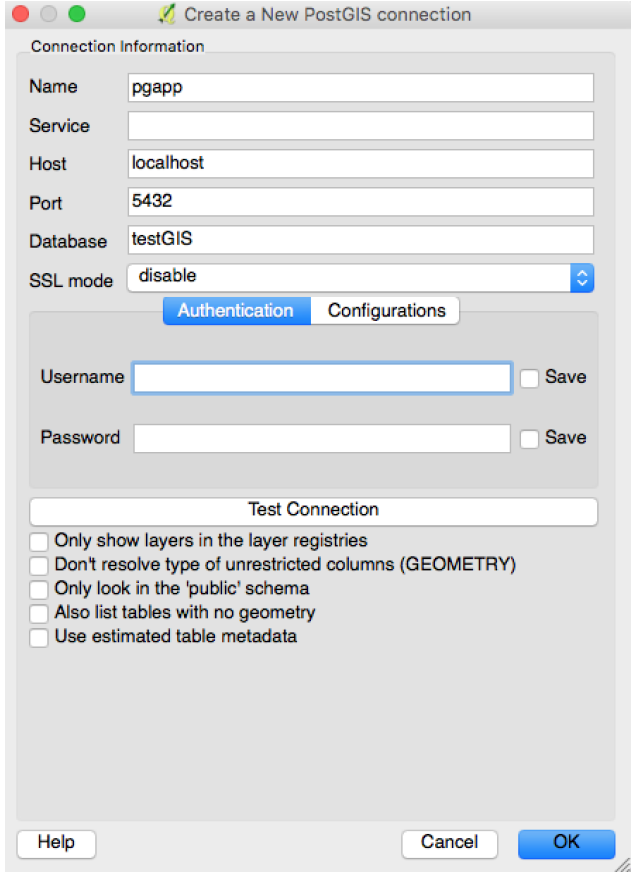
e.g. the canton polygons
(TLM_KANTONSGEBIET)



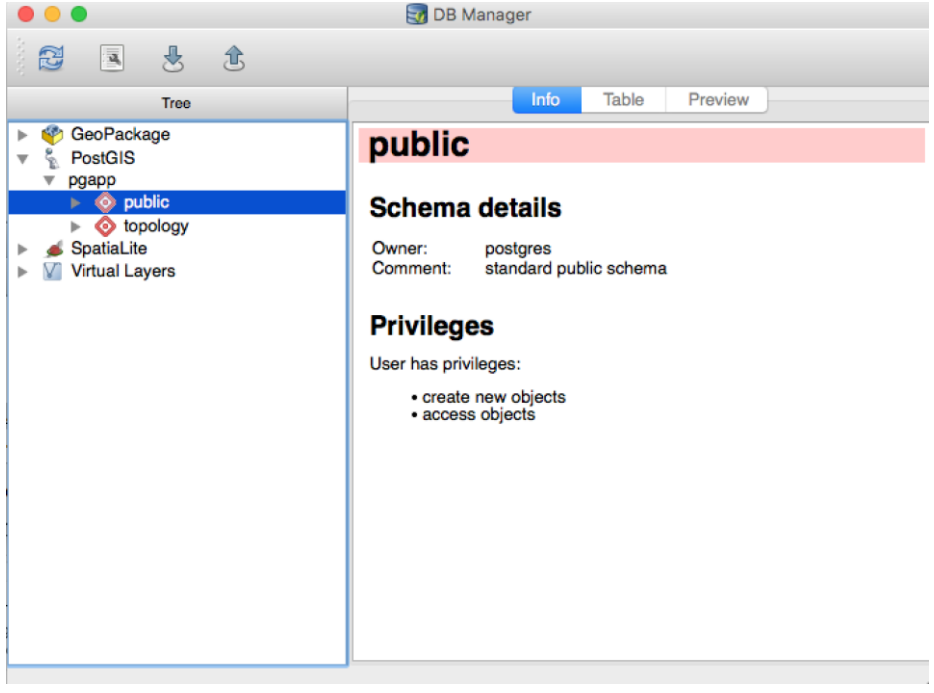
> Loading Shapefiles

Connect to PostGIS from QGIS:
PostGIS->new connection



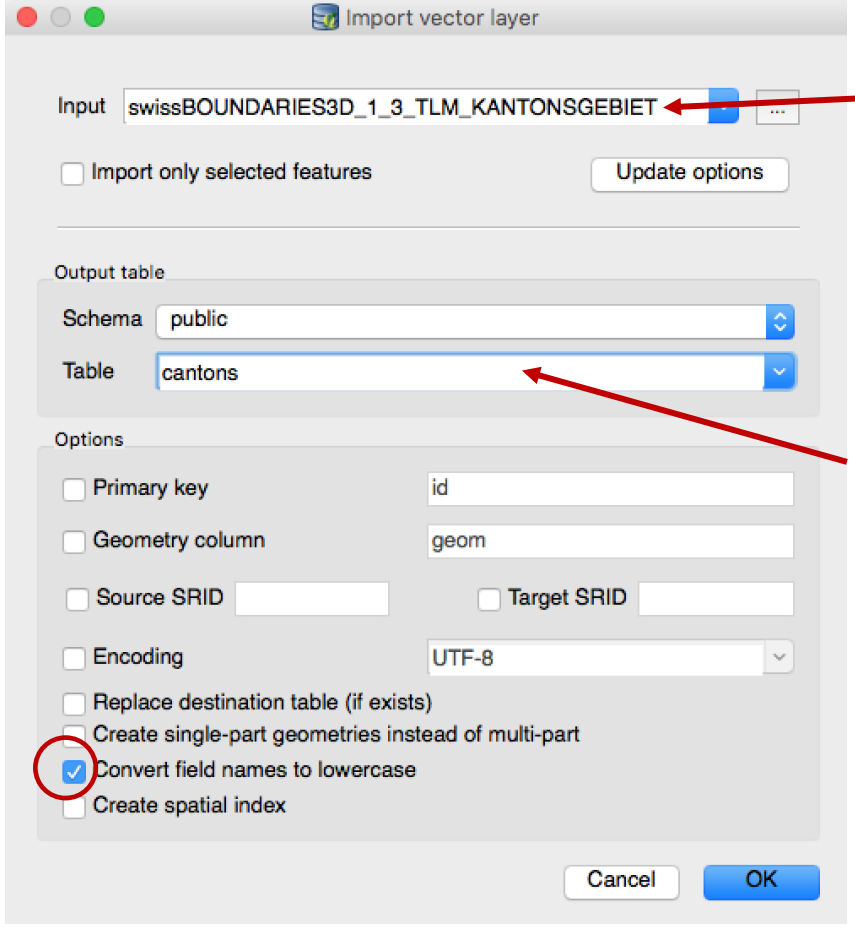


Then from the QGIS menu
Database->DBManager



> Loading Shapefiles

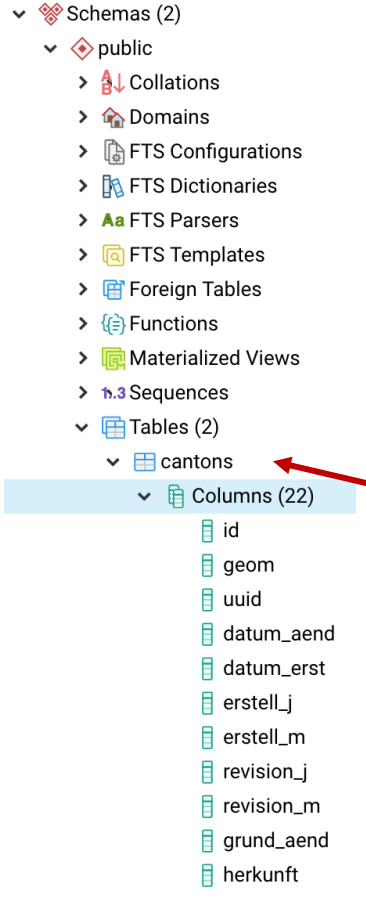
Then import the vector layer as a new table 'cantons'



shapefile layer

new table

Go back to pgAdmin, and refresh, the new table is there:

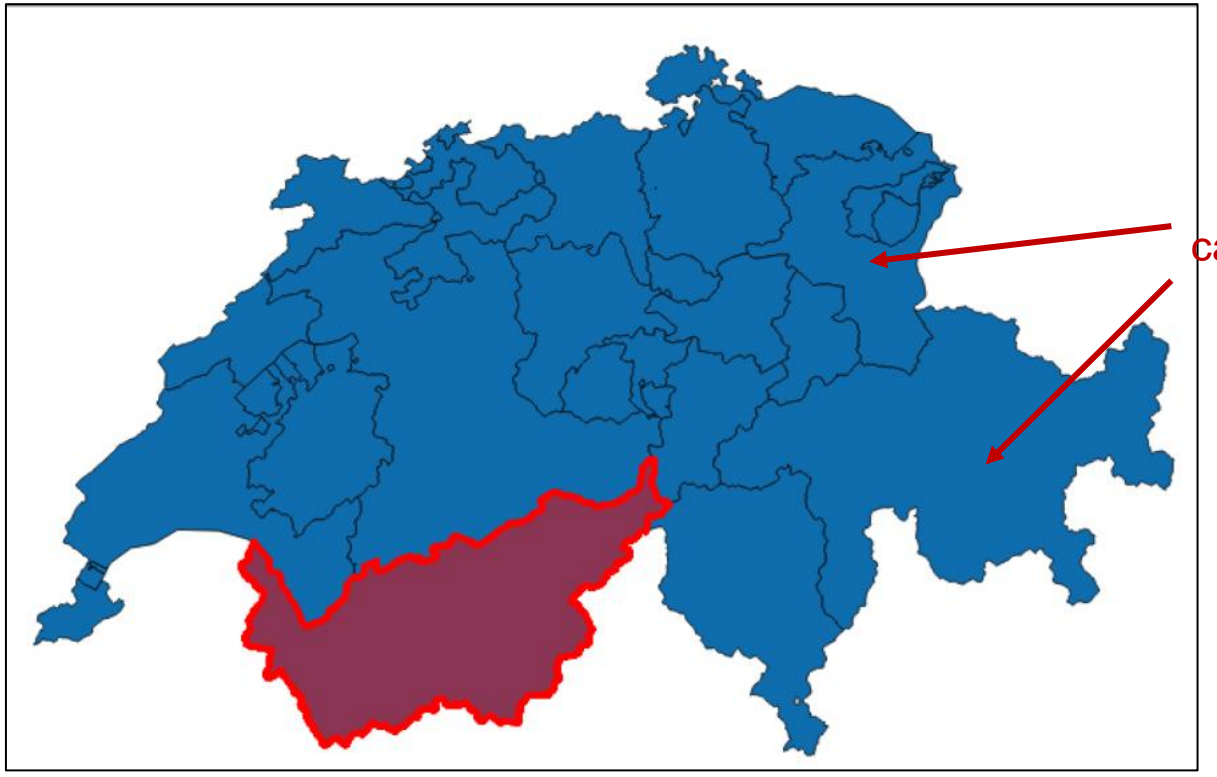


new table and imported columns

> Loading Shapefiles

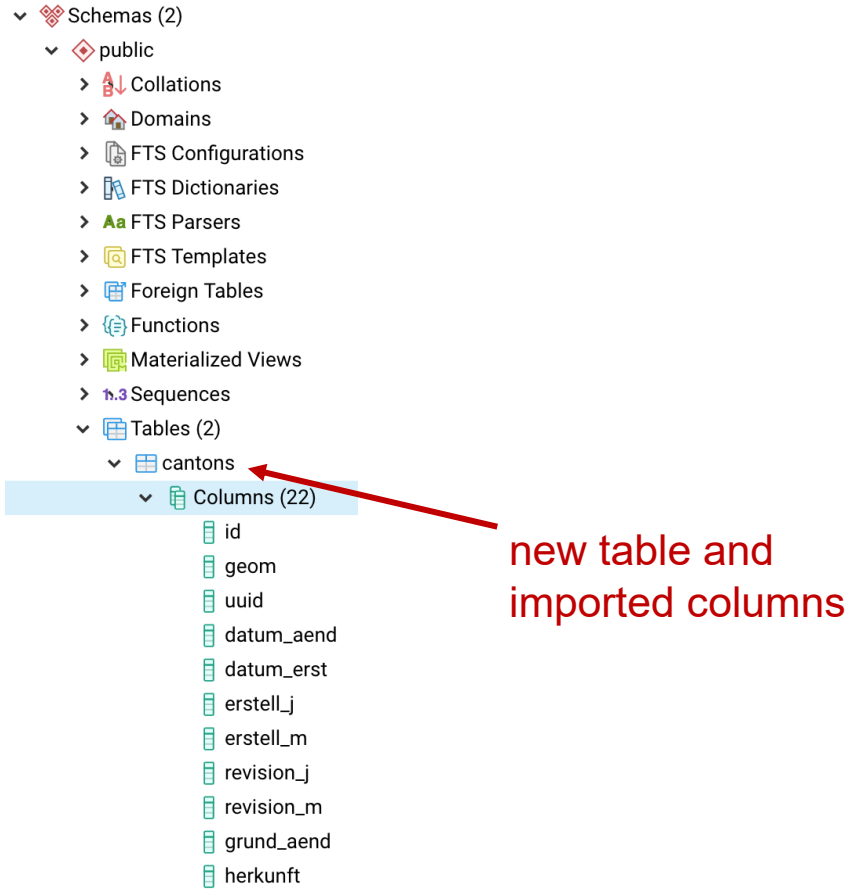
Load with command line tool shp2pgsql:

```
> shp2pgsql.exe -I -s 21781
swissBOUNDARIES3D_1_3_TLM_KANTONSGEBIET.shp cantons |
psql.exe –h localhost –p 5433 -d postgres -U postgres
```



> Loading Shapefiles

Go back to pgAdmin, and refresh,
the new table is there:



new table and
imported columns

> Querying

Get all from the cantons

```
SELECT * FROM cantons;
```

Data Output | Explain | Messages | Notifications | Geometry Viewer

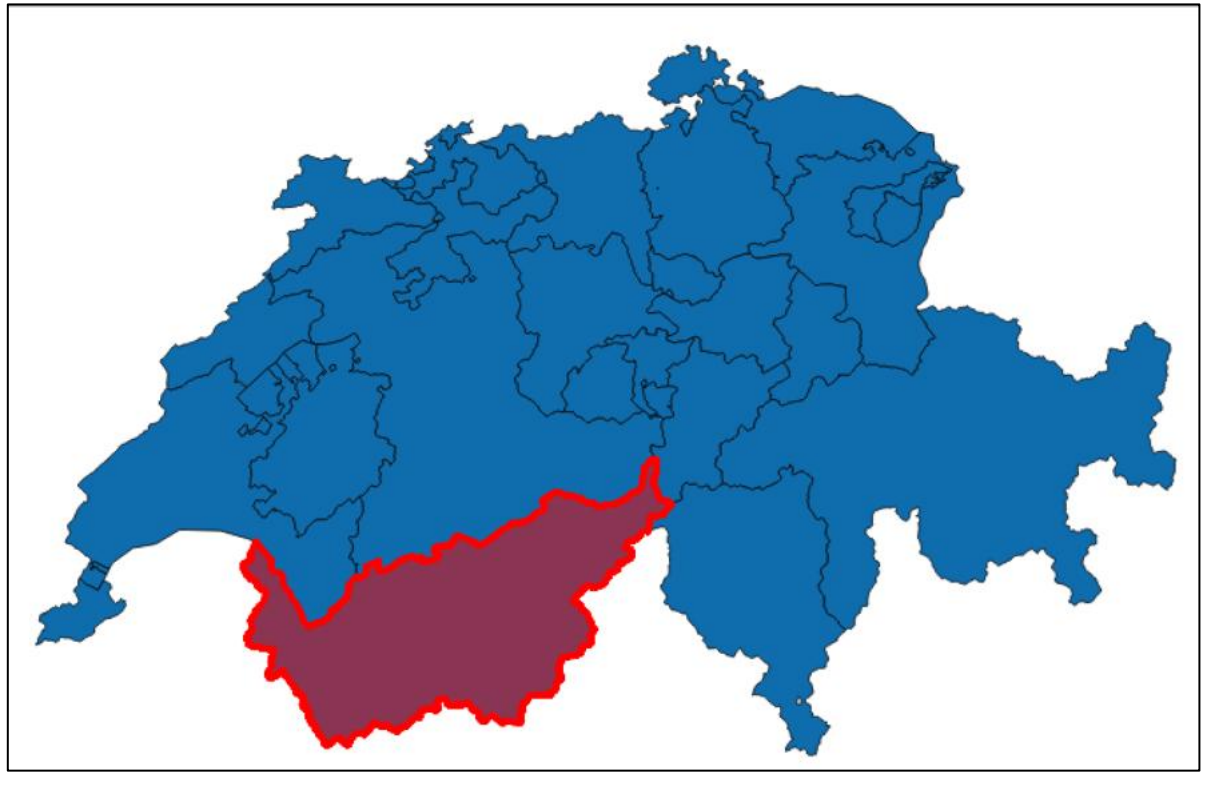
	id integer	geom geometry	uuid character varying (38)	datum_aend date	datum_erst date	erstell_j integer	erstell_m character varying (20)
1	1	01060000A0155...	{0B2364ED-49E0-4D53-A3...	2018-11-22	2012-10-26	2012	10
2	2	01060000A0155...	{DDD56CEF-0E61-4EED-8...	2018-11-22	2012-10-26	2012	10
3	3	01060000A0155...	{54B25E50-30A7-4995-AD...	2018-11-22	2012-10-26	2012	10
4	4	01060000A0155...	{921DFEF2-6D91-4CB8-9C...	2018-11-22	2012-10-26	2012	10
5	5	01060000A0155...	{95F10F52-8B2F-4D6A-AF...	2018-11-22	2012-10-26	2012	10
6	6	01060000A0155...	{05D55405-466B-4ECC-83...	2017-12-04	2012-10-26	2012	10
7	7	01060000A0155...	{FB7105B8-6D7C-4787-84...	2018-11-22	2012-10-26	2012	10
8	8	01060000A0155...	{B01E1FB4-9A9B-48AC-B...	2015-12-09	2012-10-26	2012	10
9	9	01060000A0155...	{A7C284E4-45C4-44E2-AB...	2016-12-09	2012-10-26	2012	10

```
SELECT name, id FROM cantons;
```

	name character varying (254)	id integer
1	Graubnden	1
2	Bern	2
3	Valais	3
4	Vaud	4
5	Ticino	5
6	St. Gallen	6
7	Zrich	7
8	Fribourg	8
9	Luzern	9

> Querying

How many cantons do we have in this representation of Switzerland?



> Querying

How many cantons in Switzerland?

```
SELECT COUNT(*) FROM cantons;
```

```
51
```

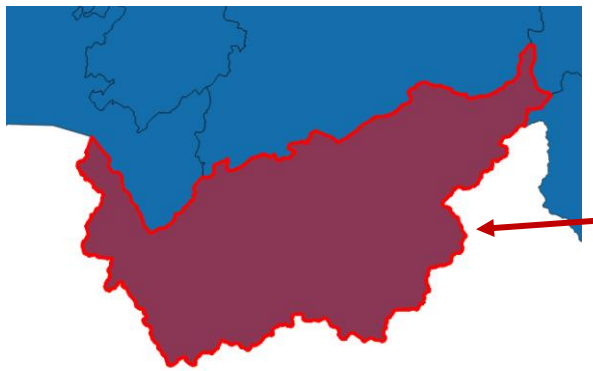
Something is wrong…

object id

OFS canton id

```
SELECT name, id, kantonsnum FROM
cantons WHERE name='Valais';
```

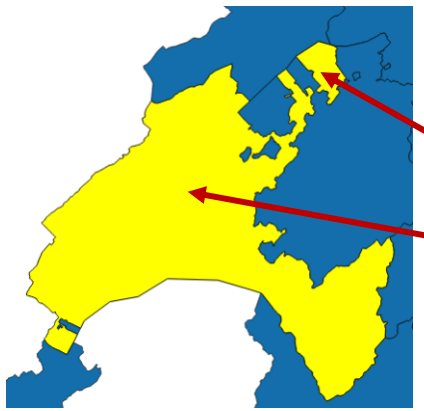
```
"Valais"        3        23
```



polygon

```
SELECT name, id, kantonsnum FROM
cantons WHERE name='Vaud';
```

```
"Vaud"          4        22
"Vaud"          27       22
```

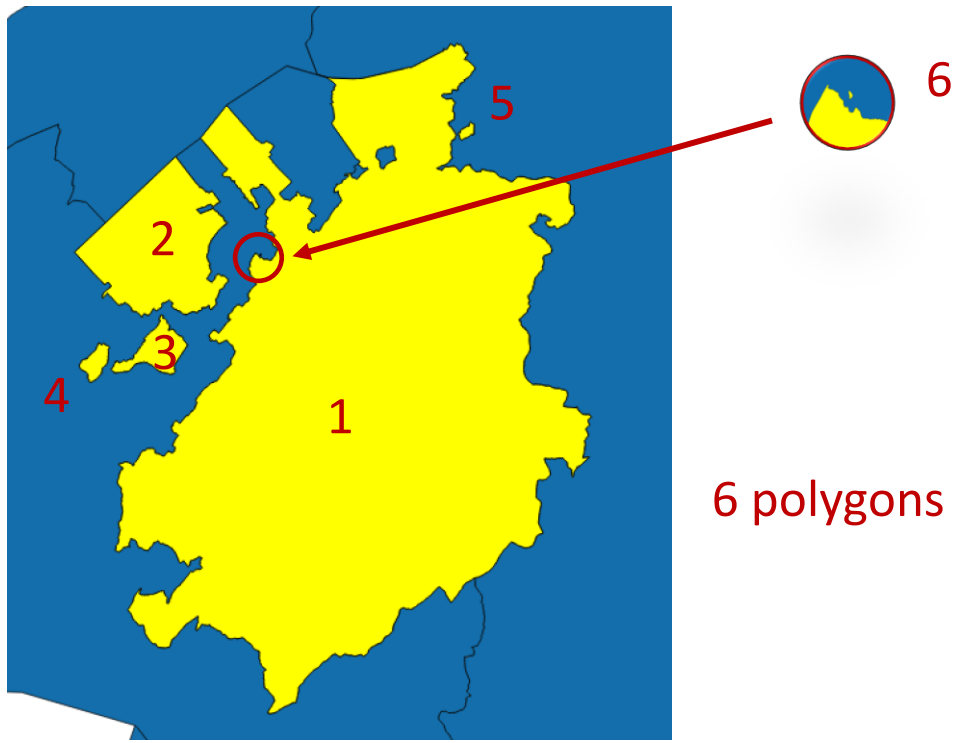


2 polygons

> Querying

```
SELECT name, id, kantonsnum,kt_teil
FROM cantons WHERE name='Fribourg';
```

"Fribourg"	8	10	"1"
"Fribourg"	26	10	"2"
"Fribourg"	32	10	"3"
"Fribourg"	49	10	"6"
"Fribourg"	38	10	"4"
"Fribourg"	44	10	"5"



> Querying

What is the area of Valais?

What is the area of Fribourg?

> Querying

What is the area of Valais?

```
SELECT name, ST_area(geom)/1000000 AS areakm2
FROM cantons WHERE name='Valais';
```

"Valais"	5224.60307347788

```
SELECT name, ST_area(geom)/1000000 AS areakm2
FROM cantons WHERE name=Fribourg';
```

"Fribourg"	1520.68684827857
"Fribourg"	127.140151939312
"Fribourg"	16.613292752175
"Fribourg"	0.00728279967471749
"Fribourg"	5.59896387173263
"Fribourg"	1.36858498091714

Individual area of all 6 polygons of Fribourg

```
SELECT sum(ST_area(geom)/1000000) AS areakm2
FROM cantons WHERE name='Fribourg';
```

1671.41512462238

Aggregated area of Fribourg

```
SELECT kantonsfla AS areaHa
FROM cantons WHERE name='Fribourg' and kt_teil ='1';
```

> Querying

What's the population and area of each canton?

Which cantons have the highest population density?

> Querying

What's the population and area of each canton?

```
SELECT name,einwohnerz, kantonsfla
FROM cantons WHERE kt_teil in ('1','0') order by einwohnerz desc;
```

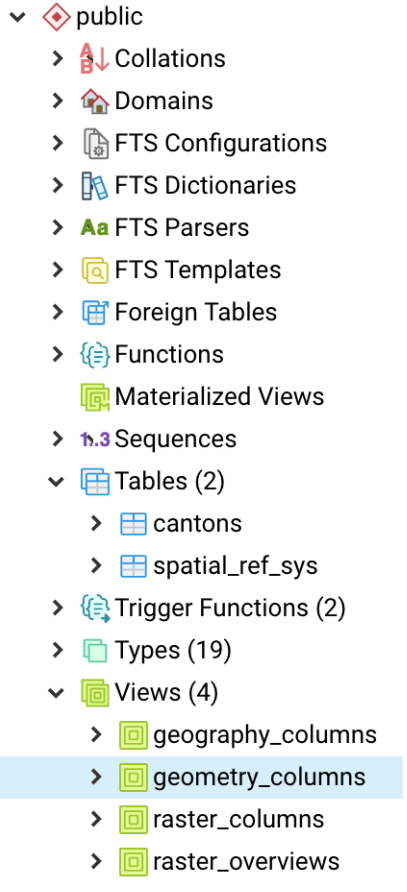
"Zrich"	1504346	"172894"
"Bern"	1031126	"595952"
"Vaud"	793129	"321201"
"Aargau"	670988	"140380"
"St. Gallen"	504686	"202820"
"Genve"	495249	"28249"
"Luzern"	406506	"149352"
"Ticino"	353709	"281216"

```
SELECT name,einwohnerz/kantonsfla as density
FROM cantons WHERE kt_teil in ('1','0') order by density desc;
```

"Basel-Stadt"	"52.4784844384303112"
"Genve"	"17.5315586392438670"
"Zrich"	"8.7009728504170185"
"Basel-Landschaft"	"5.5445167770973786"
"Zug"	"5.2536757005822477"
"Aargau"	"4.7797976919789144"
"Solothurn"	"3.4338920867860080"
"Thurgau"	"2.7536230426518359"
"Schaffhausen"	"2.7260572347697875"

ordered by
population density

> PostGIS metadata




```
select * from geometry_columns;
```

```
"testGIS"    "public"    "cantons"    "geom"    3    21781    "MULTIPOLYGON"
```

geometry column — 3 dimensions — SRID

```
select * from spatial_ref_sys where srid=21781;
```

```
"21781    "EPSG"    21781    "PROJCS["CH1903 / LV03",GEOGCS["CH1903",DATUM["CH1903",SPHEROID["Bessel 1841",6377397.155,299.1528128,AUTHORITY["EPSG","7004"]],TOWGS84[674.374,15.056,405.346,0,0,0,0],AUTHORITY["EPSG","6149"]],PRIMEM["Greenwich",0,AUTHORITY["EPSG","8901"]],UNIT["degree",0.0174532925199433,AUTHORITY["EPSG","9122"]],AUTHORITY["EPSG","4149"]],PROJECTION["Hotine_Oblique_Mercator_Azimuth_Center"],PARAMETER["latitude_of_center",46.95240555555556],PARAMETER["longitude_of_center",7.439583333333333],PARAMETER["azimuth",90],PARAMETER["rectified_grid_angle",90],PARAMETER["scale_factor",1],PARAMETER["false_easting",600000],PARAMETER["false_northing",200000],UNIT["metre",1,AUTHORITY["EPSG","9001"]],AXIS["Y",EAST],AXIS["X",NORTH],AUTHORITY["EPSG","21781"]]"

"+proj=somerc +lat_0=46.95240555555556 +lon_0=7.439583333333333 +k_0=1 +x_0=600000 +y_0=200000 +ellps=bessel +towgs84=674.374,15.056,405.346,0,0,0,0 +units=m +no_defs "
```

> Spatial operations

- ST_Contains(A, B): no points of B lie in the exterior of A, and at least one point of the interior of B lies in the interior of A.
- ST_Crosses(A, B): the supplied geometries have some, but not all, interior points in common.
- ST_Disjoint(A, B): the Geometries do not share any space together.
- ST_Distance(A, B): 2-dimensional cartesian minimum distance
- ST_DWithin(A, B, radius): the geometries are within the specified distance of one another.
- ST_Equals(A, B): the given geometries represent the same geometry
- ST_Intersects(A, B): the Geometries share any portion of space
- ST_Overlaps(A, B): the Geometries share space, are of the same dimension, but are not completely contained by each other.
- ST_Touches(A, B): the geometries have at least one point in common, but their interiors do not intersect.
- ST_Within(A, B): the geometry A is completely inside geometry B

> Spatial queries

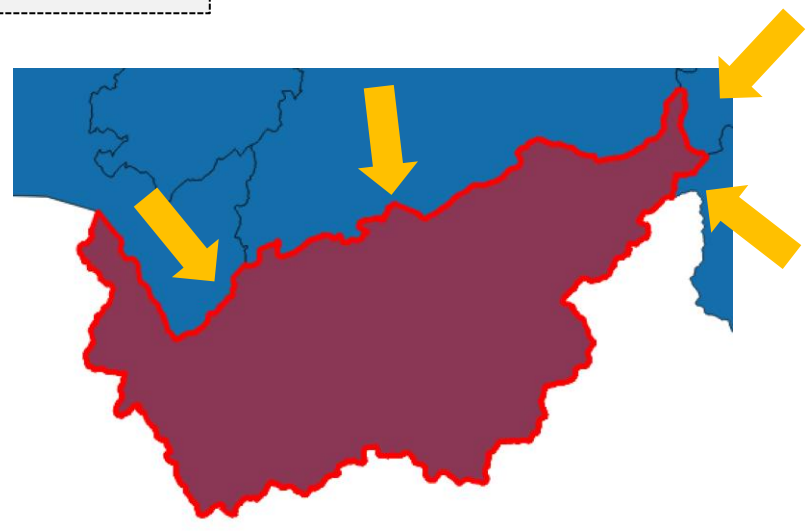
Which cantons border (touch) the canton of Valais?

> Spatial queries

Which cantons border (touch) the canton of Valais

```
SELECT c2.name, c2.kt_teil
FROM cantons c1, cantons c2
WHERE ST_Touches(c1.geom,c2.geom)
and c1.name='Valais' and c1.id<>c2.id;
```

"Bern"	"1"
"Vaud"	"1"
"Ticino"	"0"
"Uri"	"0"

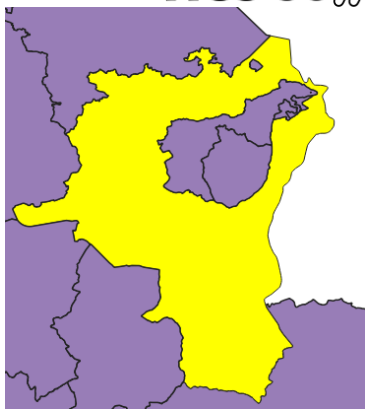


> Spatial queries

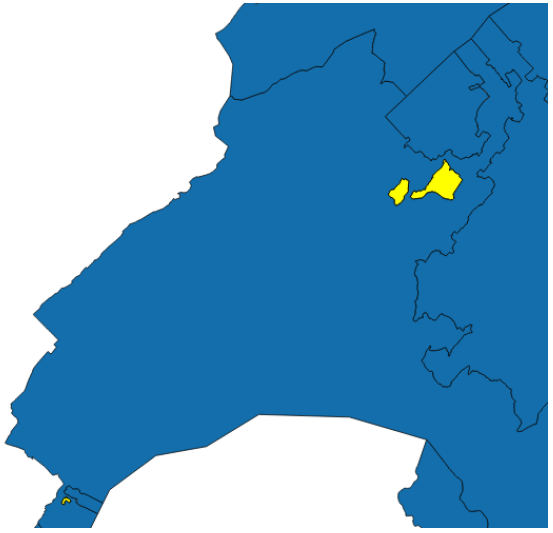
Which are the top 5 cantons with smaller borders?

> Spatial queries

Which cantons are contained in St Gallen?



Which cantons are (partially) contained in Vaud?

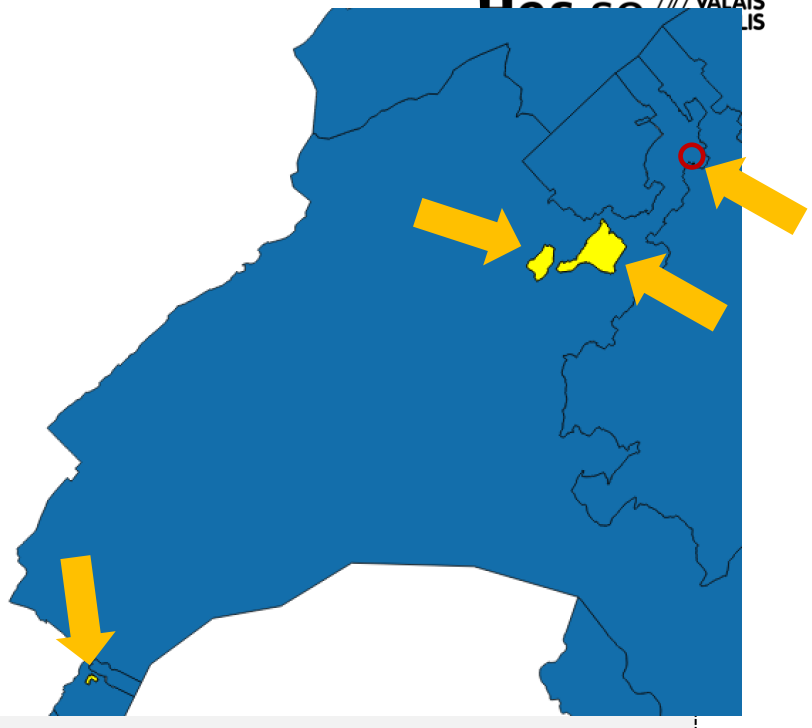


> Spatial queries

Which cantons are (partially) contained in Vaud?

```
select c2.name, c2.kt_teil
from cantons c1, cantons c2
where ST_Contains(c1.geom,c2.geom) and
c1.name='Vaud' and c1.id<>c2.id;
```

No results!

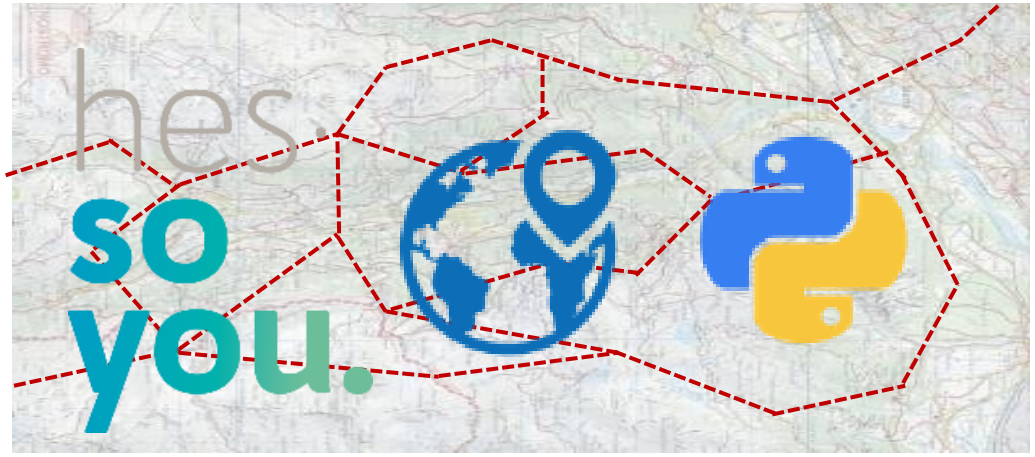


```
select c2.name, c2.kt_teil
from cantons c1, cantons c2
where ST_Contains(
  ST_Polygon(ST_ExteriorRing(ST_GeometryN(c1.geom,1)),21781),
  c2.geom)
and c1.name='Vaud' and c1.id<>c2.id;
```

Create polygon with the exterior of the canton border

SRID

```
"Fribourg"   "3"
"Fribourg"   "6"
"Fribourg"   "4"
"Genve"      "3"
```



Thank you for your attention.

School of Management
Route de la Plaine 2
3960 Sierre

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