Topology in PostgreSQL / PostGIS

Vincent Picavet – Oslandia

https://github.com/Oslandia/presentations/tree/master/pgconf_eu_2012

Summary

Topology ??

Why ?

PostGIS topology

PgRouting

Recursive queries

Example on Hydrology network

Topology ???

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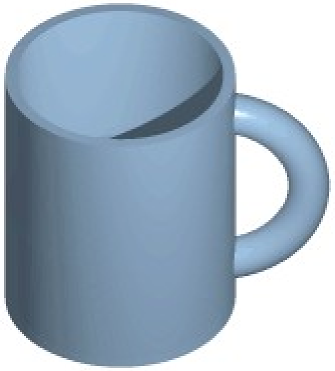
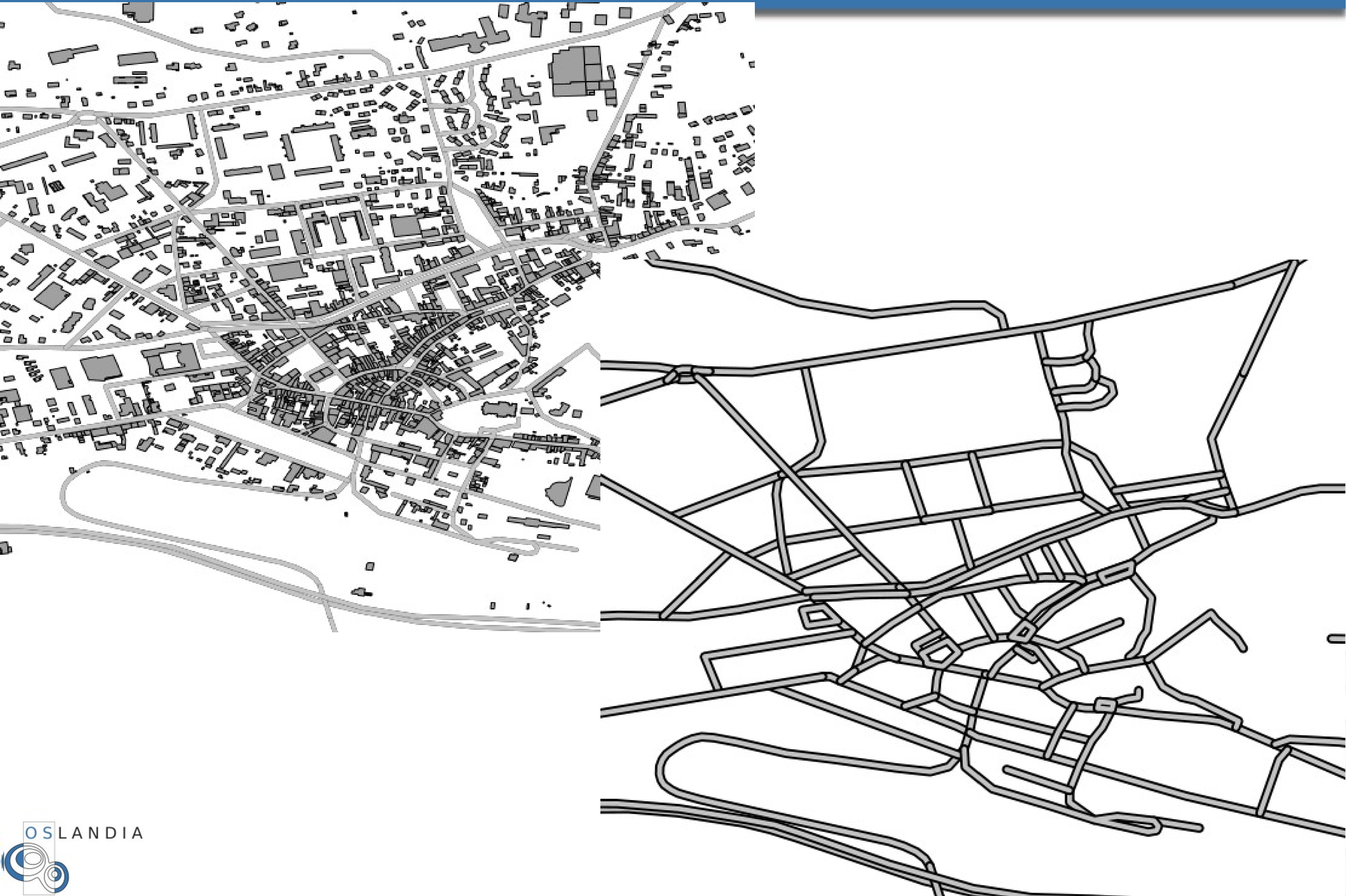
« **Topology** is a major area of **mathematics** concerned with the most basic **properties of space**, such as **connectedness**. »



« **Geospatial topology** studies the **rules** concerning the **relationships** between the points, lines, and polygons that represent the **features** of a geographic region. »

In GIS…

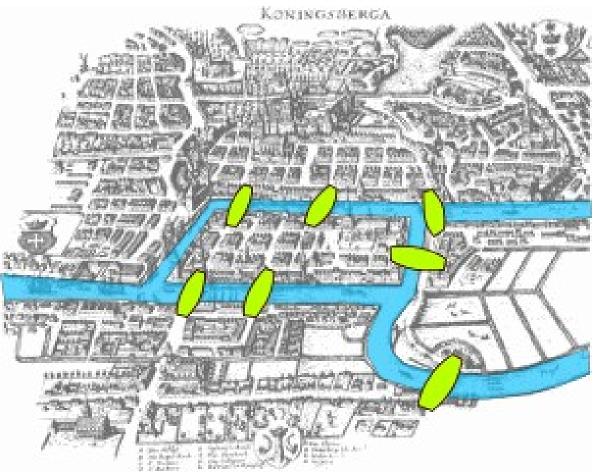


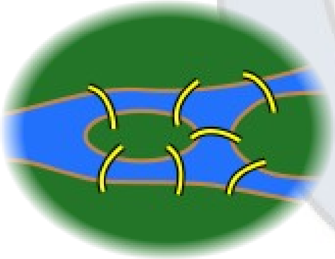
Spaghetti model

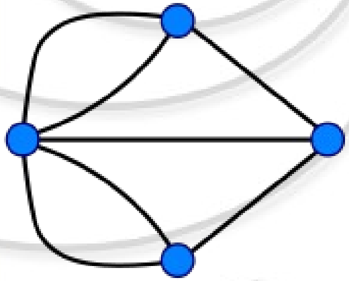
Beware of the spaghetti monster !

Topology - Graphs

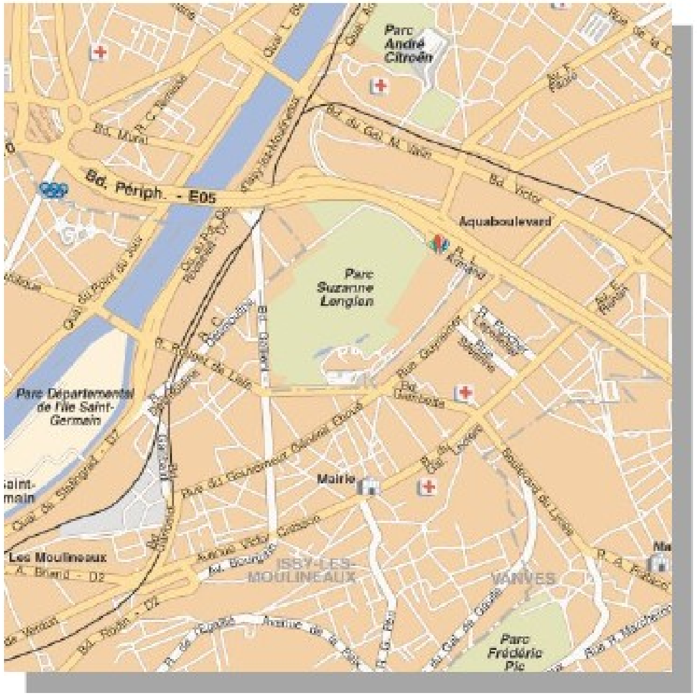
- Explicit relations between objects
- Graph representation
- Various types of graphs and networks
  - Node / edge / face

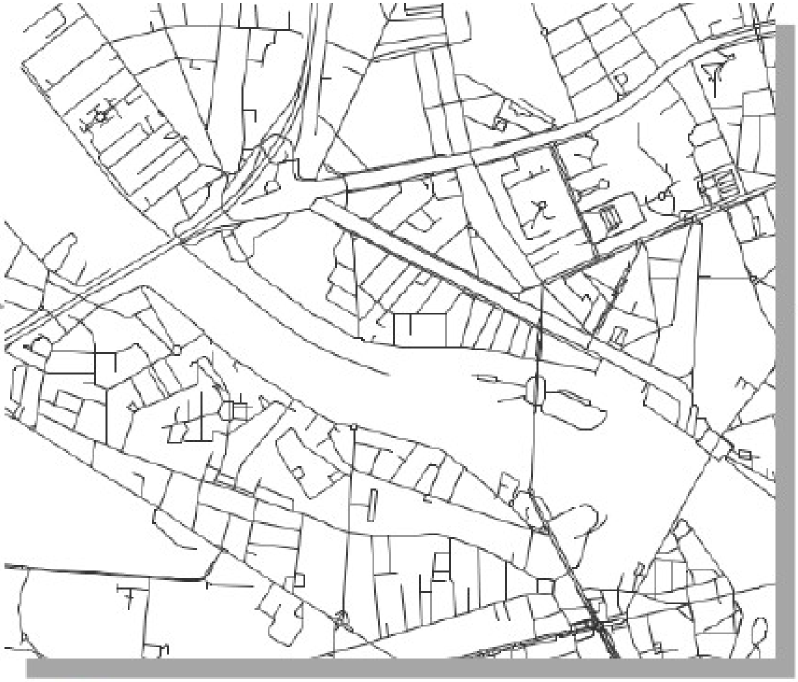


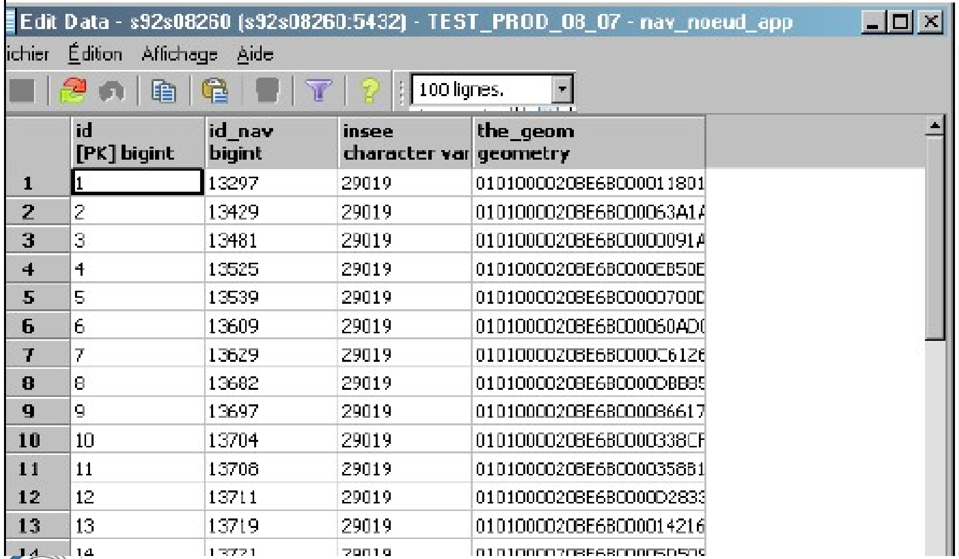




Graphs in database






Edit Data - s92s08260 (s92s08260:5432) - TEST_PROD_08_07 - nav_noeud_app
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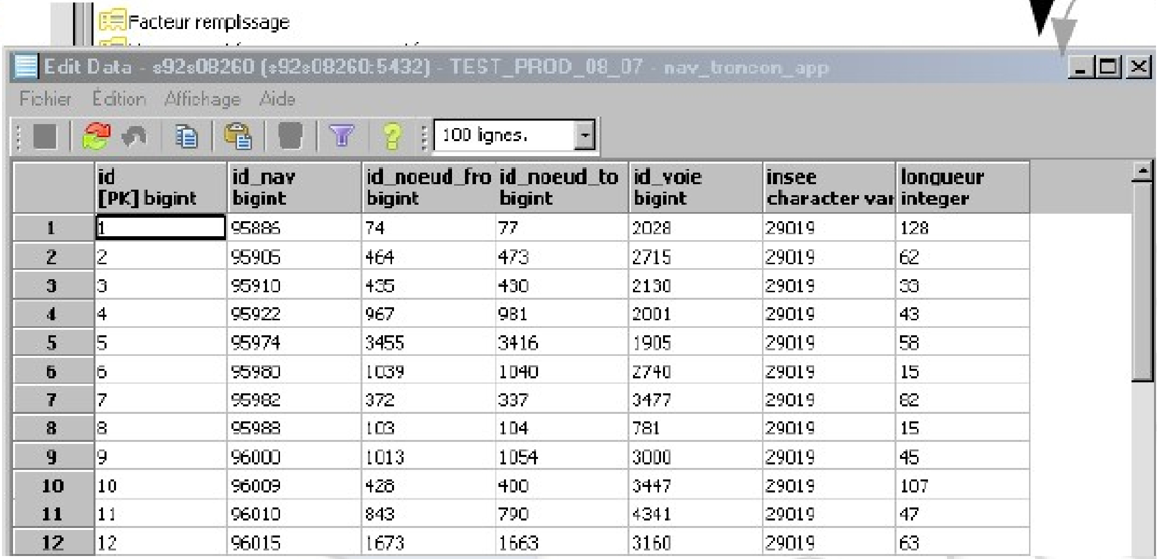
100 lignes.

	id [PK] bigint	id_nav bigint	insee character var	the_geom geometry
1	1	13297	29019	0101000020BE6B0001180
2	2	13429	29019	0101000020BE6B00063A1A
3	3	13481	29019	0101000020BE6B0000091A
4	4	13525	29019	0101000020BE6B000EB50E
5	5	13539	29019	0101000020BE6B0000700D
6	6	13609	29019	0101000020BE6B00060AD(
7	7	13629	29019	0101000020BE6B000C6126
8	8	13682	29019	0101000020BE6B000DBB85
9	9	13697	29019	0101000020BE6B0008661 7
10	10	13704	29019	0101000020BE6B000338CF
11	11	13708	29019	0101000020BE6B00035881
12	12	13711	29019	0101000020BE6B000D2833
13	13	13719	29019	0101000020BE6B00014216
14	14	13721	29019	0101000020BE6B00005D5C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Edit Data - s92s08260 (s92s08260:5432) - TEST_PROD_08_07 - nav_troncon_app
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	id [PK] bigint	id_nav bigint	id_noeud_fro bigint	id_noeud_to bigint	id_voie bigint	insee character var	longueur integer
1	1	95886	74	77	2028	29019	128
2	2	95905	464	473	2715	29019	62
3	3	95910	435	430	2130	29019	33
4	4	95922	967	981	2001	29019	43
5	5	95974	3455	3416	1905	29019	58
6	6	95980	1039	1040	2740	29019	15
7	7	95982	372	337	3477	29019	82
8	8	95988	103	104	781	29019	15
9	9	96000	1013	1054	3000	29019	45
10	10	96009	428	400	3447	29019	107
11	11	96010	843	790	4341	29019	47
12	12	96015	1673	1663	3160	29019	63

Why ?

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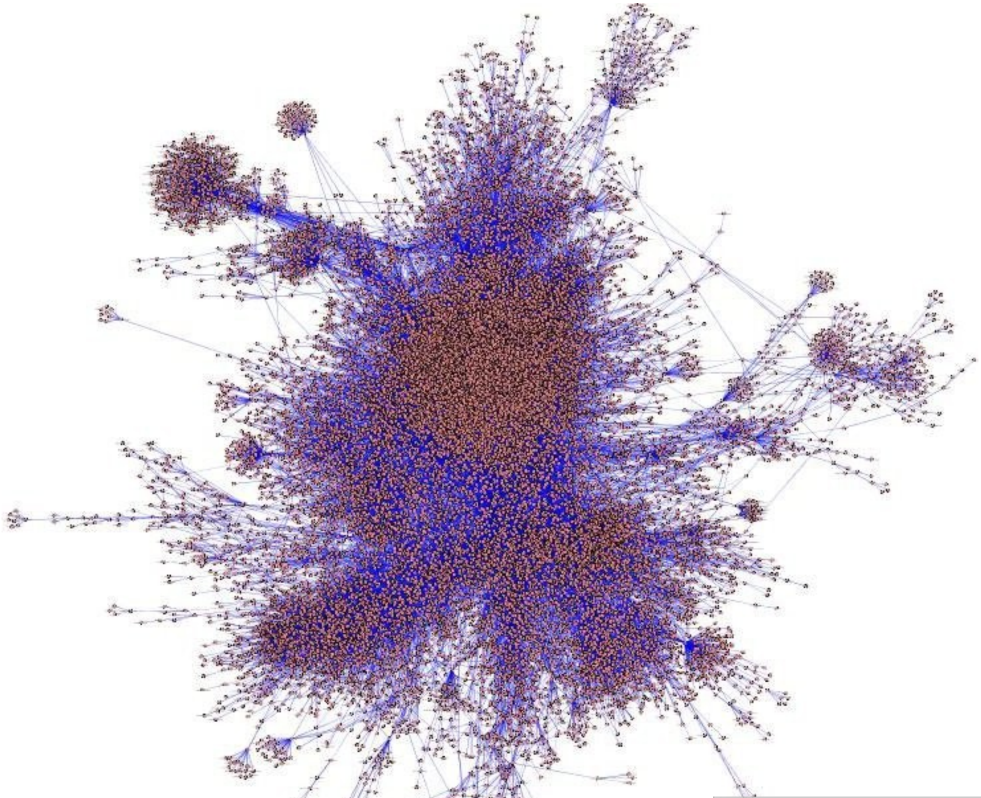
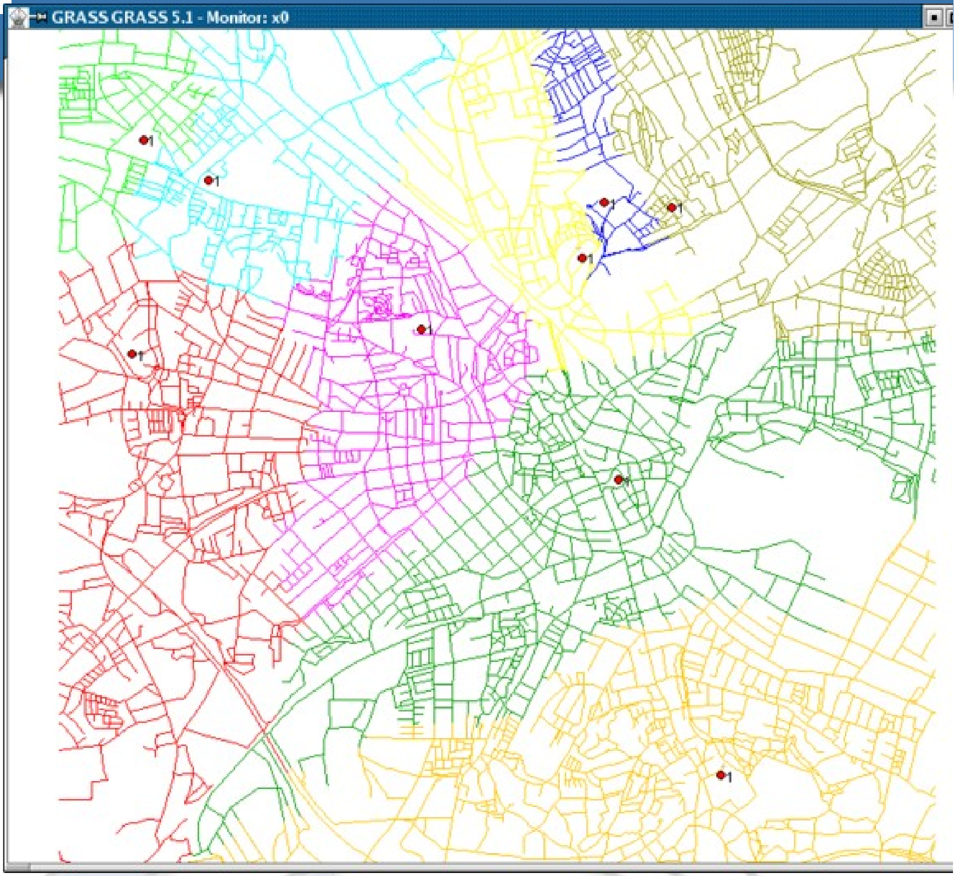
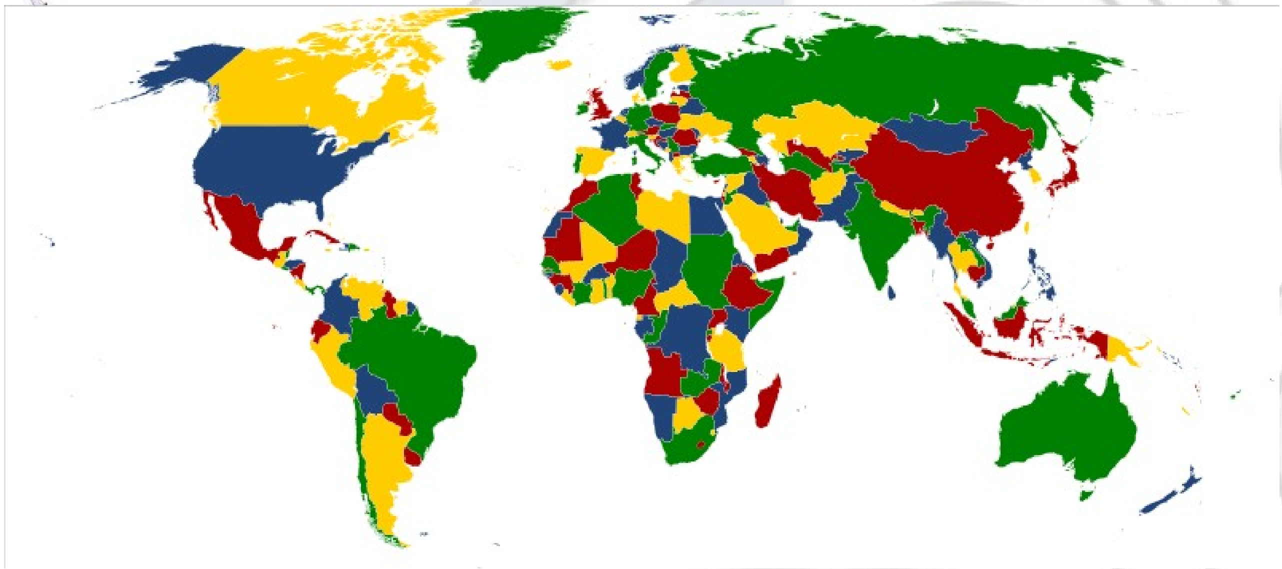
Why ?







Why ?

Normalized spatial data

Standard interface

Topological integrity

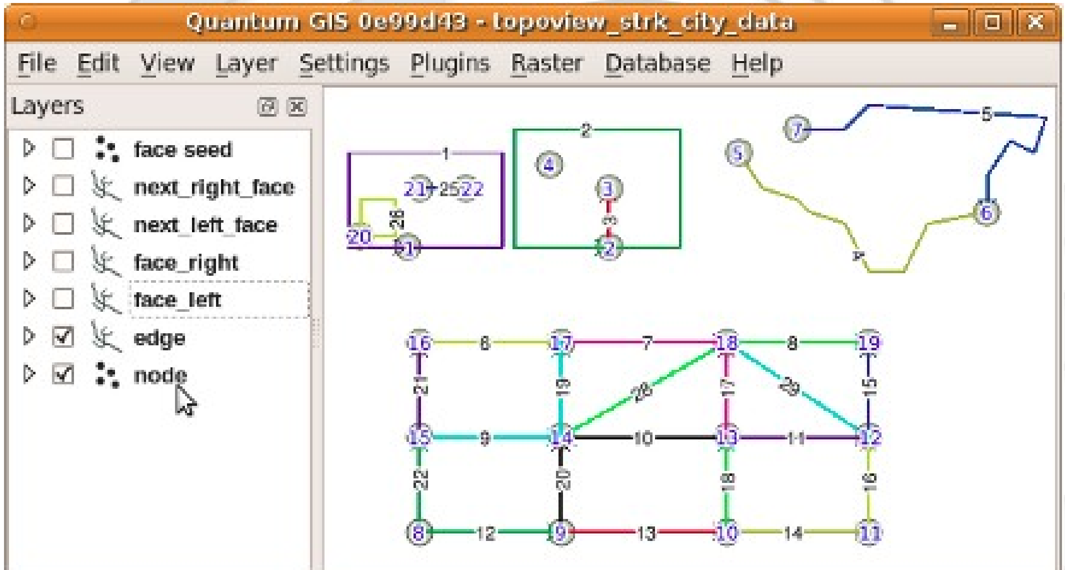
Reduced storage size

Explicit spatial relationships

PostGIS Topology

PostGIS Topology

- Initiated long ago
- ISO SQL/MM implementation
- In PostGIS 2.0
- Sandro Santilli (Toscana Region, IT)
- Still under development



Quantum GIS 0e99d43 - topoview_strk_city_data

- □ face seed
- □ next_right_face
- □ next_left_face
- □ face_right
- □ face_left
- ☑ edge
- ☑ node

PostGIS Topology – Concepts

- Node / Edge / Face model
- Uses schema :
  - 1 General «topology» schema
  - 1 schema per topology
  - mytopo.{edge, face, node, relation}
- Metadata tables on topologies and layers
  - topology.{topology, layer}
- TopoGeometry Datatype
- Cast to geometry

PgRouting

PgRouting

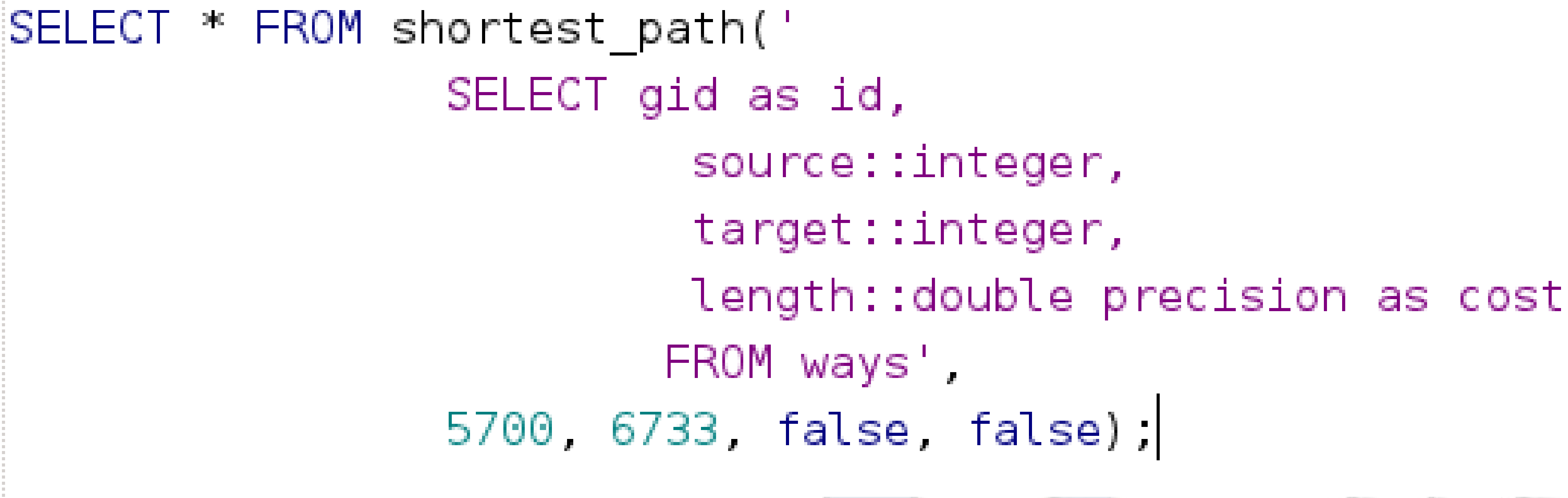
- OSS PostgreSQL / PostGIS plugin
- Based on Boost Graph
- Live computation inside the database
- Various algorithms
  - Shortest Path Dijkstra
  - Shortest Path A-Star
  - Shortest Path Shooting-Star
  - Traveling Salesperson Problem (TSP)
  - Driving Distance calculation (Isolines)

PgRouting – data

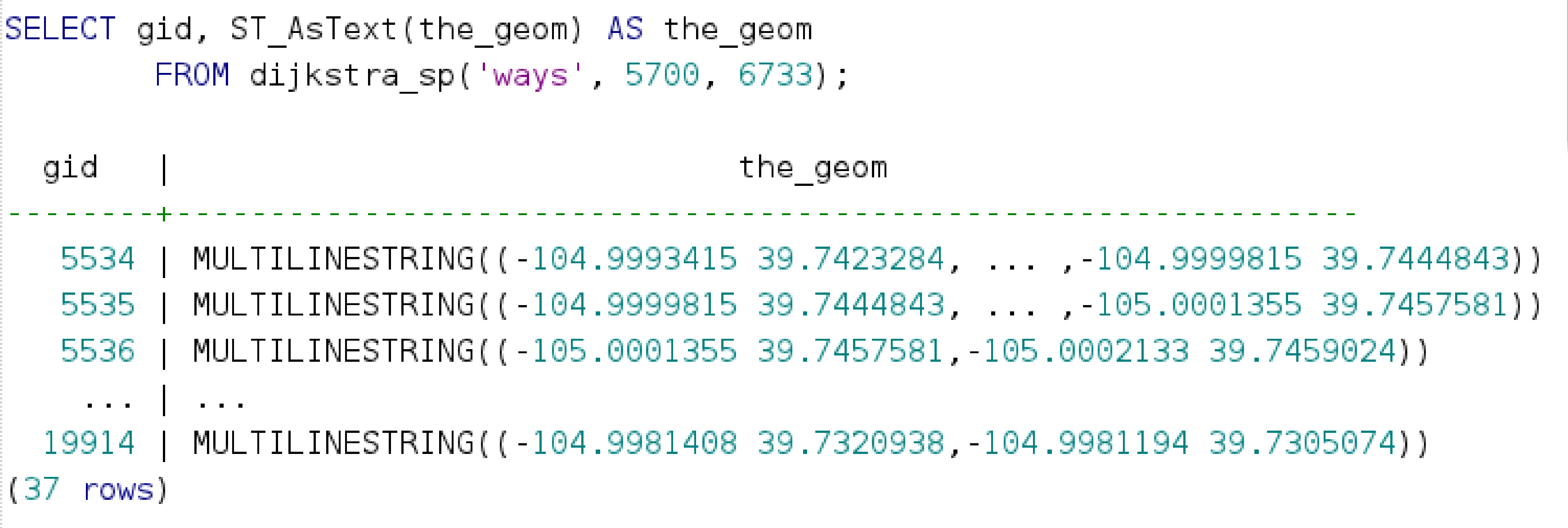
- For Dijkstra : edges
- gid, source, target, cost
- Source and target : node ids
- Cost : any value
  - Field value
  - pre-computed (length)
  - computed on the fly
  - computed with complex queries on live data

PgRouting – Example

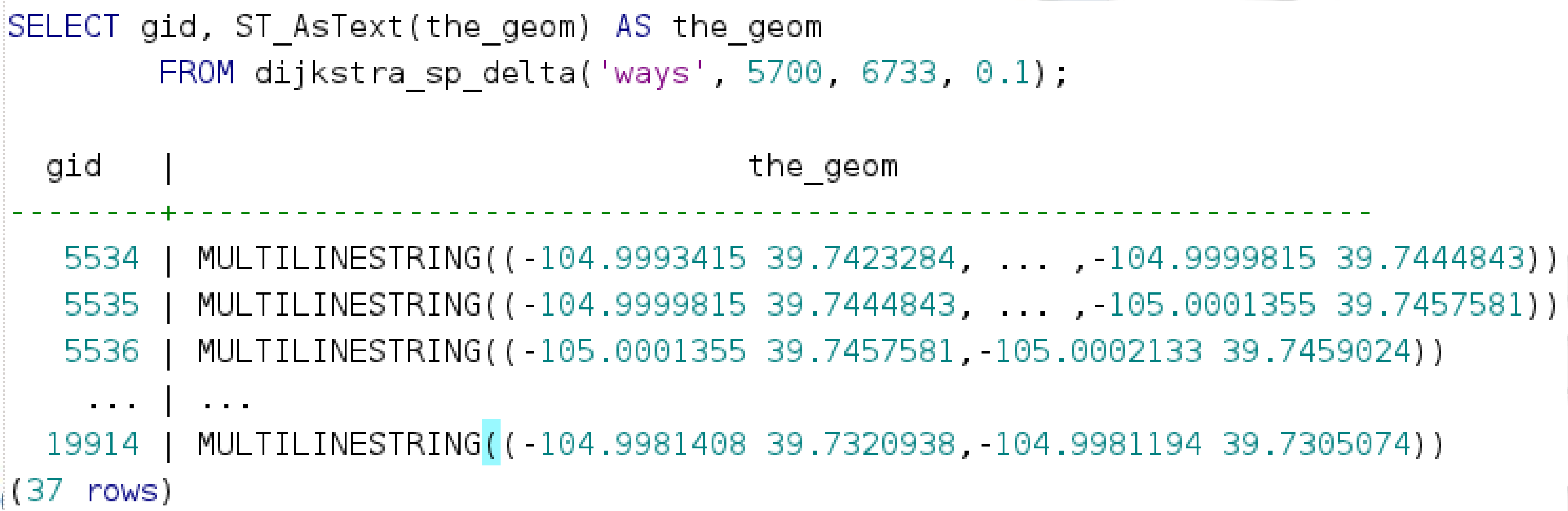
Dijkstra



```
SELECT * FROM shortest_path('
                SELECT gid as id,
                         source::integer,
                         target::integer,
                         length::double precision as cost
                        FROM ways',
                5700, 6733, false, false);
```



```
SELECT gid, ST_AsText(the_geom) AS the_geom
       FROM dijkstra_sp('ways', 5700, 6733);

  gid   |                    the_geom
--------+---------------------------------------------
   5534 | MULTILINESTRING((-104.9993415 39.7423284, ... ,-104.9999815 39.7444843))
   5535 | MULTILINESTRING((-104.9999815 39.7444843, ... ,-105.0001355 39.7457581))
   5536 | MULTILINESTRING((-105.0001355 39.7457581,-105.0002133 39.7459024))
    ... | ...
  19914 | MULTILINESTRING((-104.9981408 39.7320938,-104.9981194 39.7305074))
(37 rows)
```



```
SELECT gid, ST_AsText(the_geom) AS the_geom
       FROM dijkstra_sp_delta('ways', 5700, 6733, 0.1);

  gid   |                    the_geom
--------+---------------------------------------------
   5534 | MULTILINESTRING((-104.9993415 39.7423284, ... ,-104.9999815 39.7444843))
   5535 | MULTILINESTRING((-104.9999815 39.7444843, ... ,-105.0001355 39.7457581))
   5536 | MULTILINESTRING((-105.0001355 39.7457581,-105.0002133 39.7459024))
    ... | ...
  19914 | MULTILINESTRING((-104.9981408 39.7320938,-104.9981194 39.7305074))
(37 rows)
```

Recursive Queries

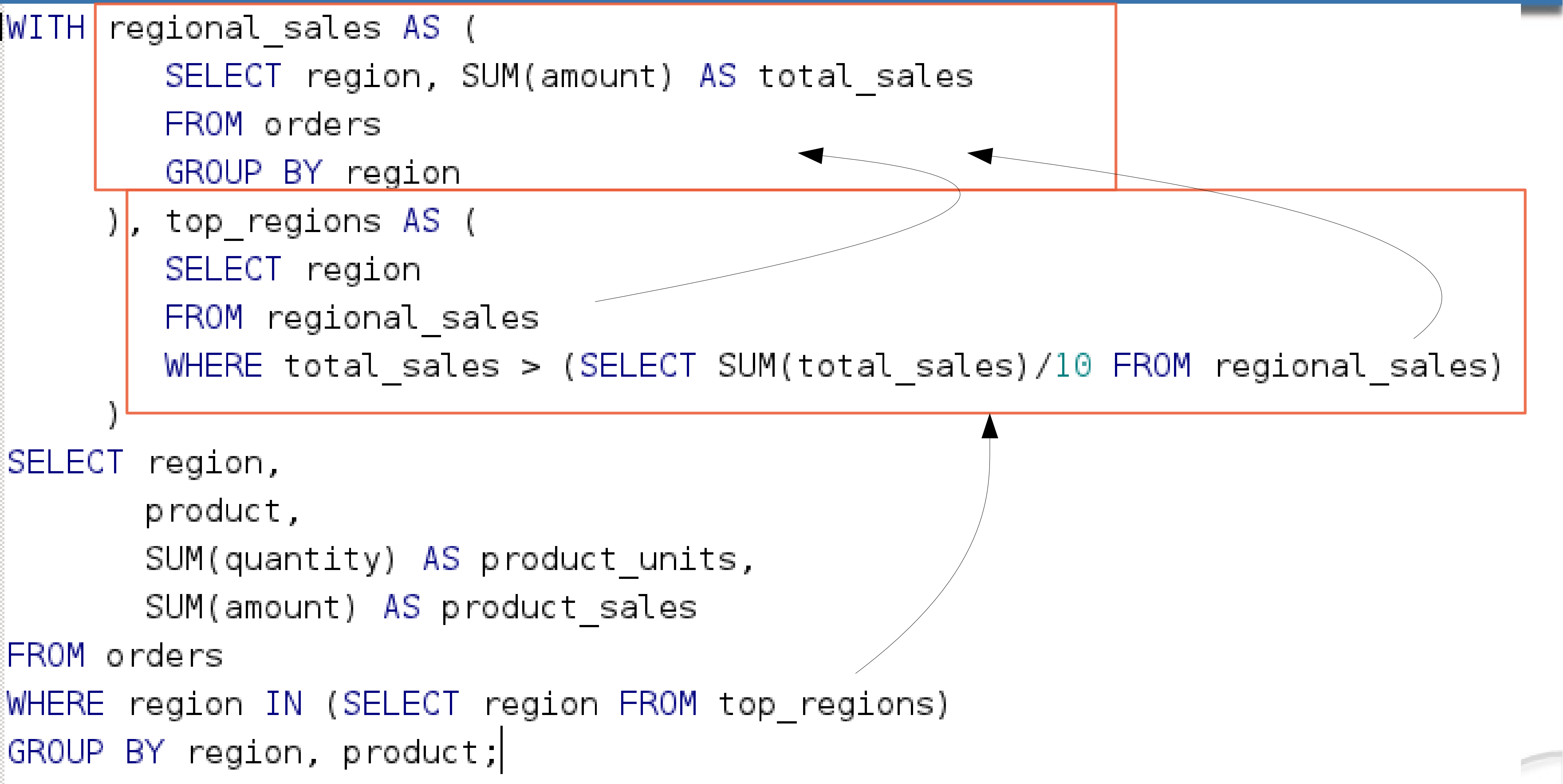
Recursive queries – principles

Common Table Expressions

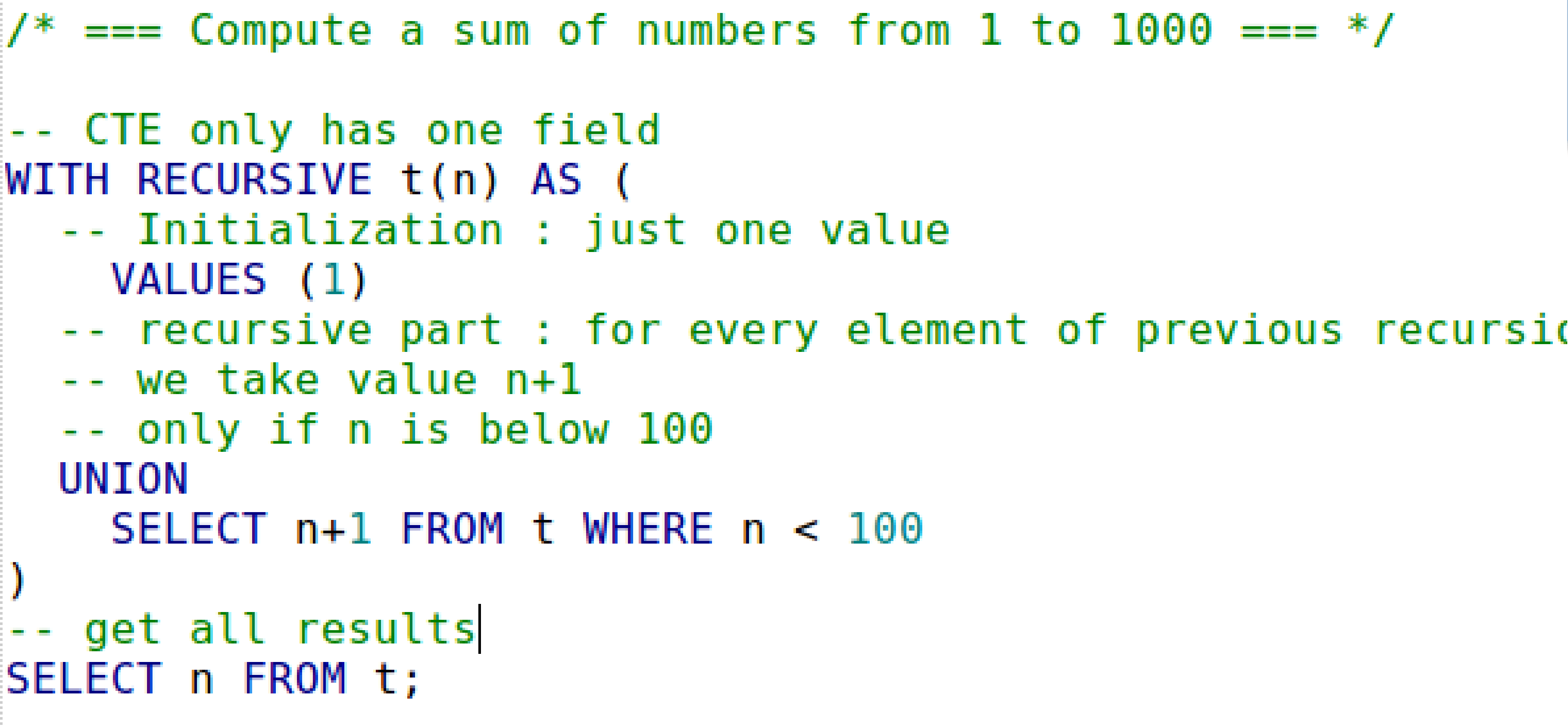
CTE in PostgreSQL 8.4+

~= temporary table

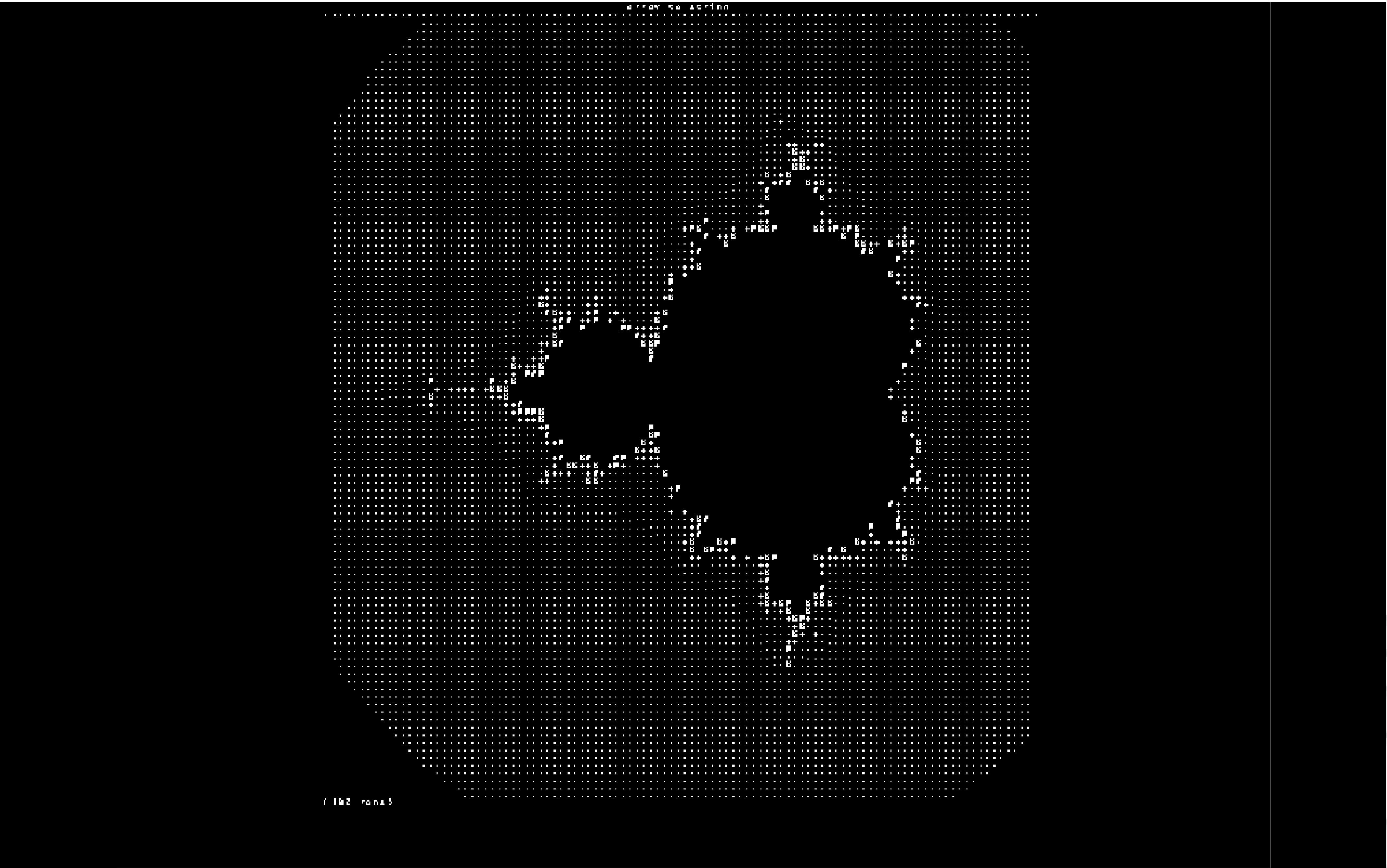
WITH RECURSIVE option



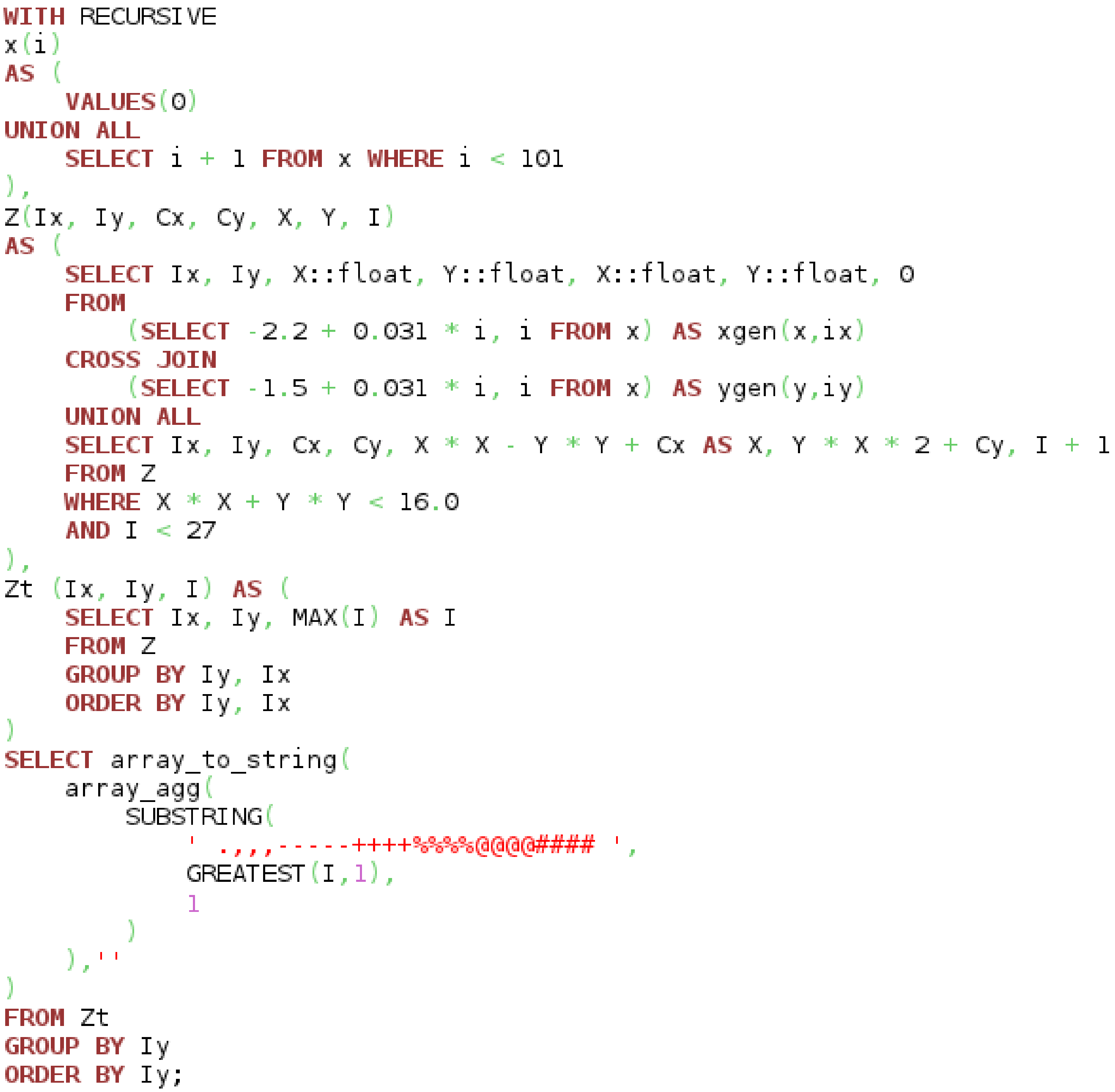
```sql
WITH regional_sales AS (
        SELECT region, SUM(amount) AS total_sales
        FROM orders
        GROUP BY region
     ), top_regions AS (
        SELECT region
        FROM regional_sales
        WHERE total_sales > (SELECT SUM(total_sales)/10 FROM regional_sales)
     )
SELECT region,
       product,
       SUM(quantity) AS product_units,
       SUM(amount) AS product_sales
FROM orders
WHERE region IN (SELECT region FROM top_regions)
GROUP BY region, product;
```



```
/* === Compute a sum of numbers from 1 to 1000 === */

-- CTE only has one field
WITH RECURSIVE t(n) AS (
  -- Initialization : just one value
    VALUES (1)
  -- recursive part : for every element of previous recursio
  -- we take value n+1
  -- only if n is below 100
  UNION
    SELECT n+1 FROM t WHERE n < 100
)
-- get all results
SELECT n FROM t;
```



```
array as ascii
(162 rows)
```



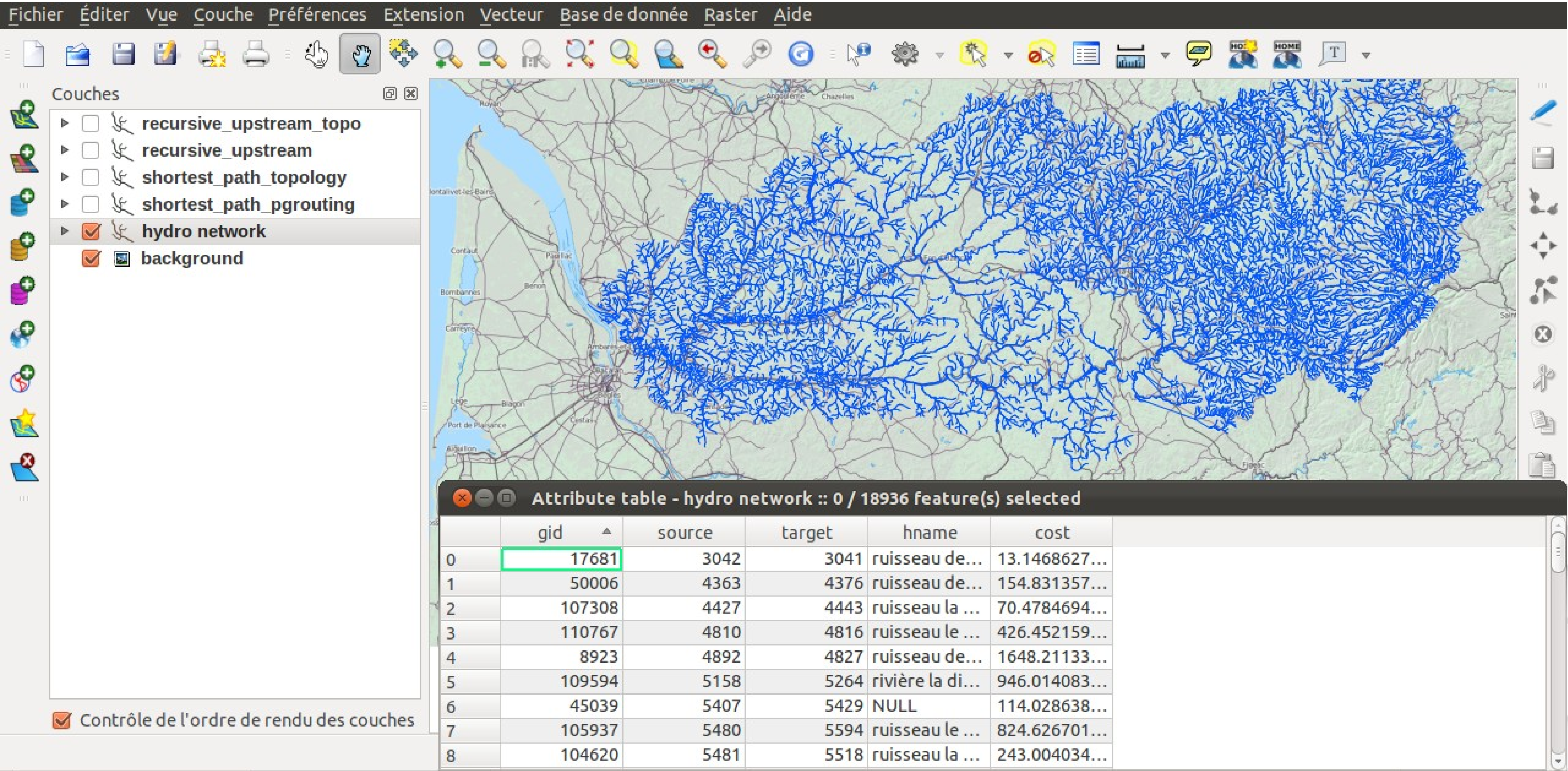
```
WITH RECURSIVE
x(i)
AS (
    VALUES(0)
UNION ALL
    SELECT i + 1 FROM x WHERE i < 101
),
Z(Ix, Iy, Cx, Cy, X, Y, I)
AS (
    SELECT Ix, Iy, X::float, Y::float, X::float, Y::float, 0
    FROM
        (SELECT -2.2 + 0.031 * i, i FROM x) AS xgen(x,ix)
    CROSS JOIN
        (SELECT -1.5 + 0.031 * i, i FROM x) AS ygen(y,iy)
    UNION ALL
    SELECT Ix, Iy, Cx, Cy, X * X - Y * Y + Cx AS X, Y * X * 2 + Cy, I + 1
    FROM Z
    WHERE X * X + Y * Y < 16.0
    AND I < 27
),
Zt (Ix, Iy, I) AS (
    SELECT Ix, Iy, MAX(I) AS I
    FROM Z
    GROUP BY Iy, Ix
    ORDER BY Iy, Ix
)
SELECT array_to_string(
    array_agg(
        SUBSTRING(
            ' .,,,-----++++%%%%@@@@#### ',
            GREATEST(I,1),
            1
        )
    ),''
)
FROM Zt
GROUP BY Iy
ORDER BY Iy;
```

Let's eat SQL !

Hydrology network

Our data

Table name : **tr**

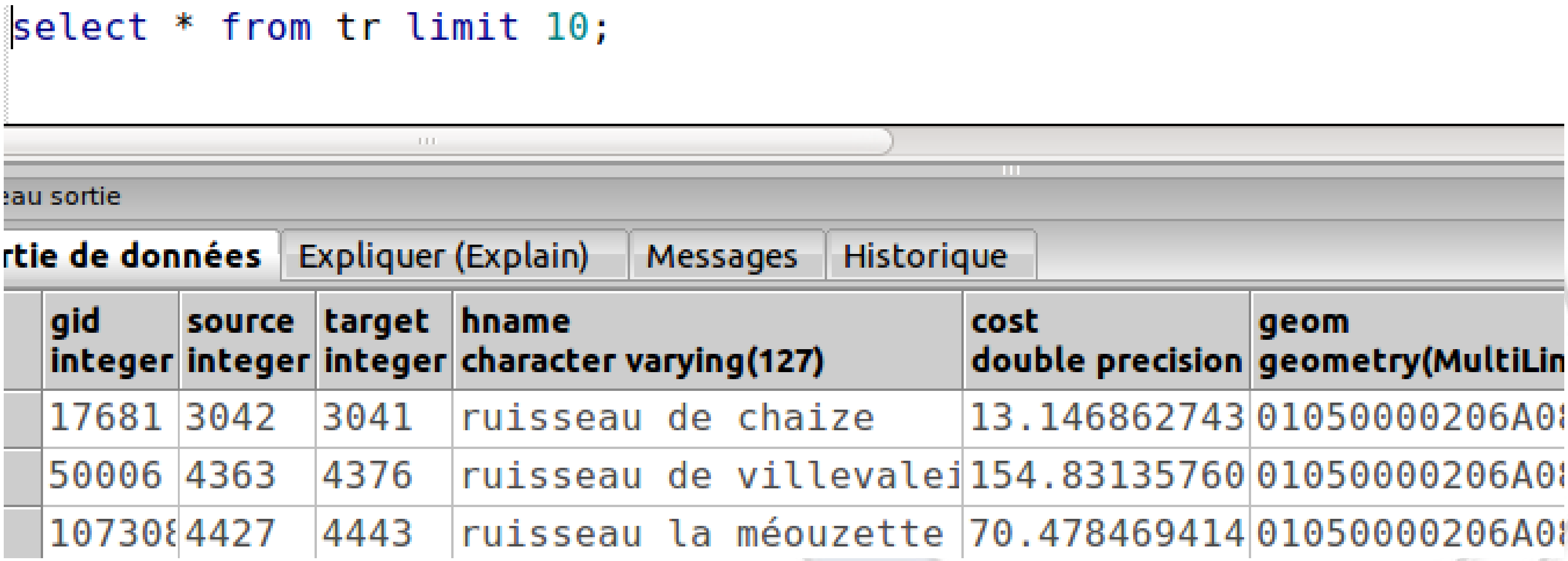


Attribute table - hydro network :: 0 / 18936 feature(s) selected

	gid	source	target	hname	cost
0	17681	3042	3041	ruisseau de...	13.1468627...
1	50006	4363	4376	ruisseau de...	154.831357...
2	107308	4427	4443	ruisseau la ...	70.4784694...
3	110767	4810	4816	ruisseau le ...	426.452159...
4	8923	4892	4827	ruisseau de...	1648.21133...
5	109594	5158	5264	rivière la di...	946.014083...
6	45039	5407	5429	NULL	114.028638...
7	105937	5480	5594	ruisseau le ...	824.626701...
8	104620	5481	5518	ruisseau la ...	243.004034...

Topology

- Geometry table = spaghetti
- Custom attribute-based topology :
  - source, target (and cost)

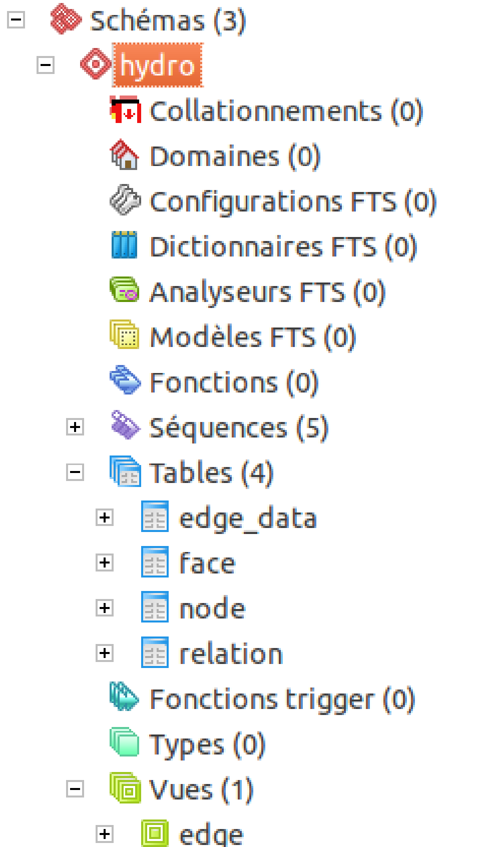


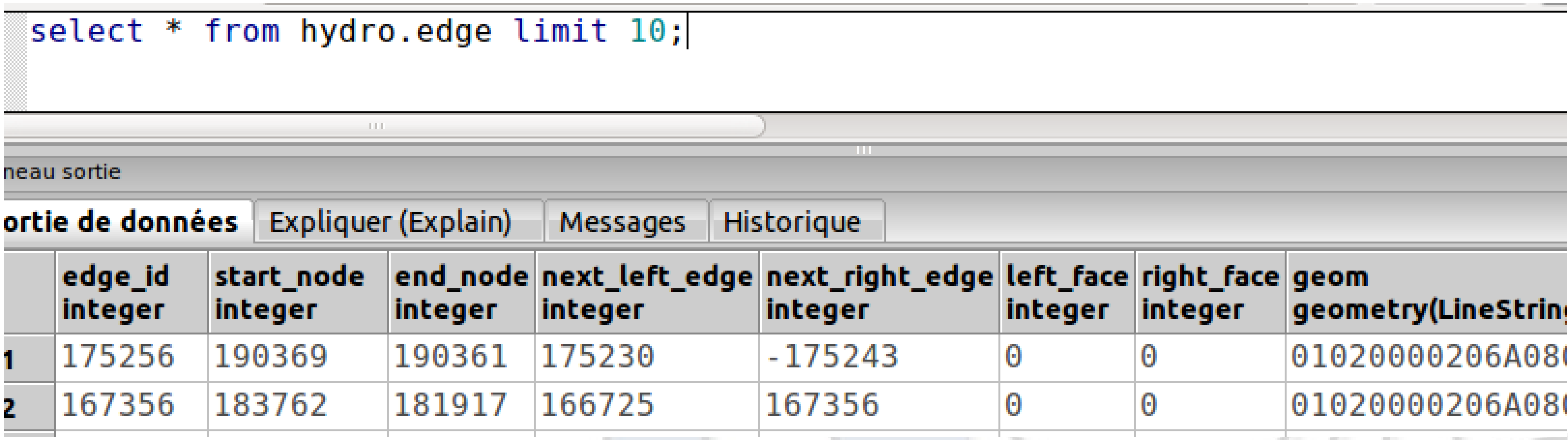
```
select * from tr limit 10;
```

gid	source	target	hname	cost	geom
integer	integer	integer	character varying(127)	double precision	geometry(MultiLin
17681	3042	3041	ruisseau de chaize	13.146862743	01050000206A0
50006	4363	4376	ruisseau de villevalei	154.83135760	01050000206A0
10730	4427	4443	ruisseau la méouzette	70.478469414	01050000206A0

- Or build a PostGIS topology based on geom

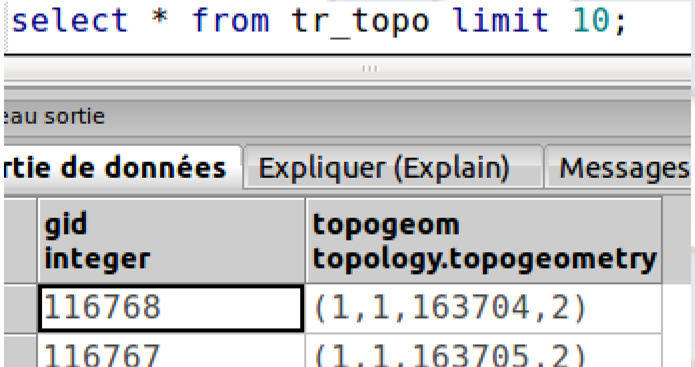
```
-- Create a topology
SELECT topology.CreateTopology('hydro', 2154);
-- 1

-- we put the postgis topology features for hydro network in another table
CREATE TABLE tr_topo (gid integer);

-- Add a layer
SELECT topology.AddTopoGeometryColumn('hydro', 'public',
        'tr_topo', 'topogeom', 'MULTILINESTRING');
-- 1

-- Populate the layer and the topology from tr geometry features
INSERT into tr_topo (gid, topogeom)
       SELECT gid, topology.toTopoGeom(geom, 'hydro', 1) FROM tr;
```





```
select * from hydro.edge limit 10;
```

	edge_id integer	start_node integer	end_node integer	next_left_edge integer	next_right_edge integer	left_face integer	right_face integer	geom geometry(LineStrin
1	175256	190369	190361	175230	-175243	0	0	01020000206A08
2	167356	183762	181917	166725	167356	0	0	01020000206A08

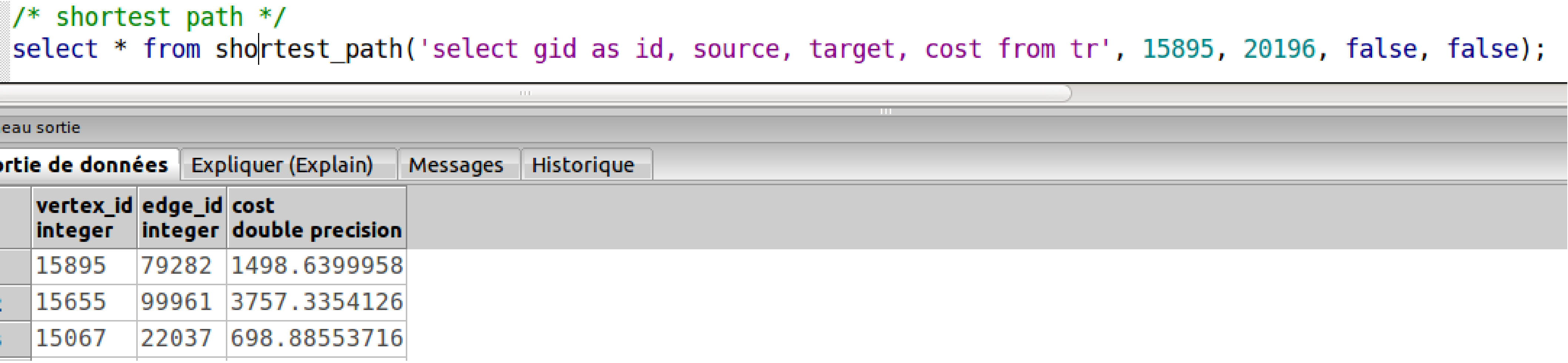


```
select * from tr_topo limit 10;
```

gid integer	topogeom topology.topogeometry
116768	(1,1,163704,2)
116767	(1,1,163705,2)

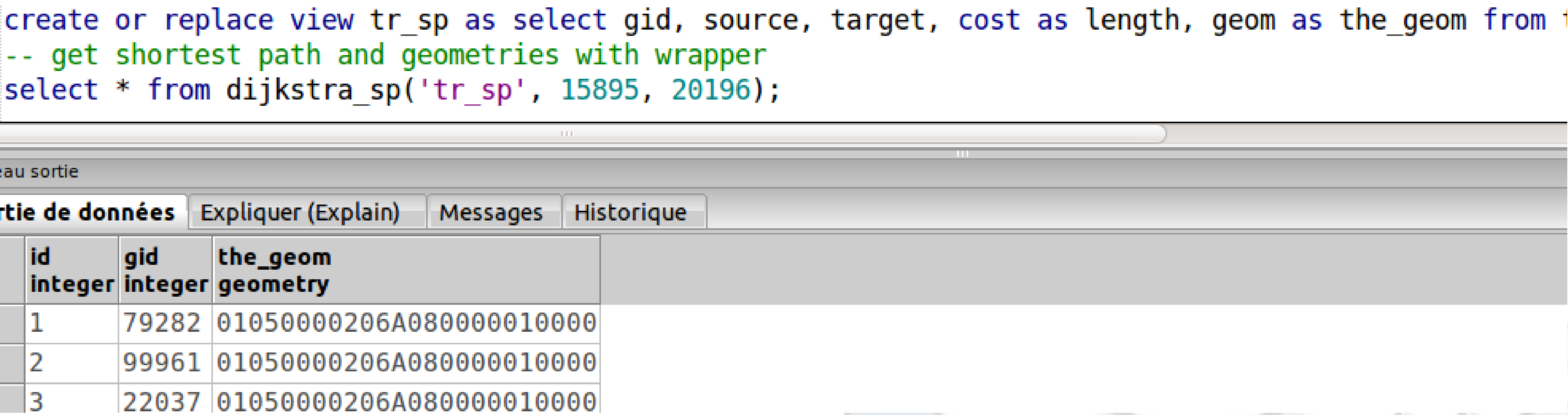
Find our way on the water

PgRouting on custom topology



```
/* shortest path */
select * from shortest_path('select gid as id, source, target, cost from tr', 15895, 20196, false, false);
```

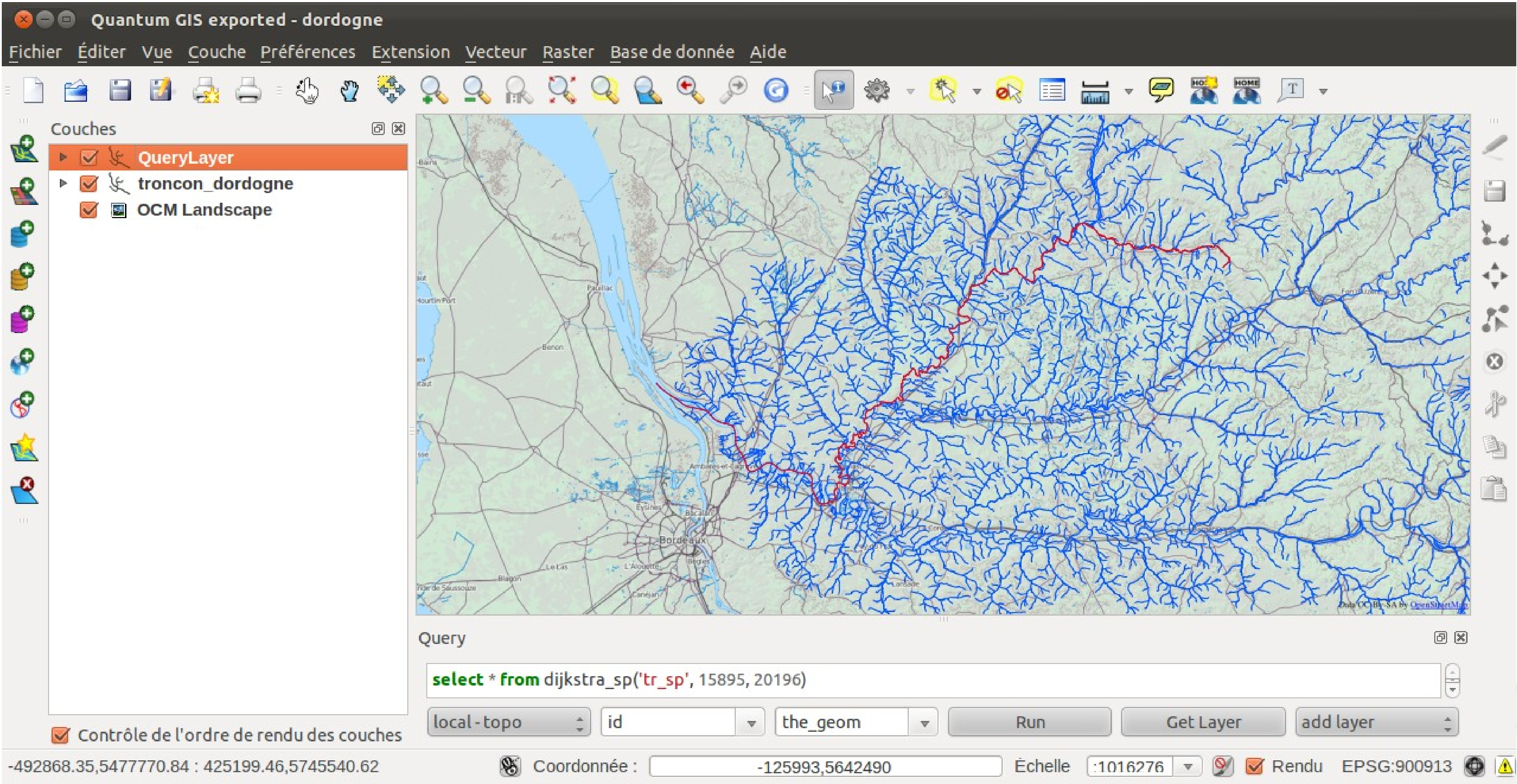
vertex_id integer	edge_id integer	cost double precision
15895	79282	1498.6399958
15655	99961	3757.3354126
15067	22037	698.88553716



```
create or replace view tr_sp as select gid, source, target, cost as length, geom as the_geom from t
-- get shortest path and geometries with wrapper
select * from dijkstra_sp('tr_sp', 15895, 20196);
```

id integer	gid integer	the_geom geometry
1	79282	01050000206A080000010000
2	99961	01050000206A080000010000
3	22037	01050000206A080000010000

PgRouting result



```
select * from dijkstra_sp('tr_sp', 15895, 20196)
```

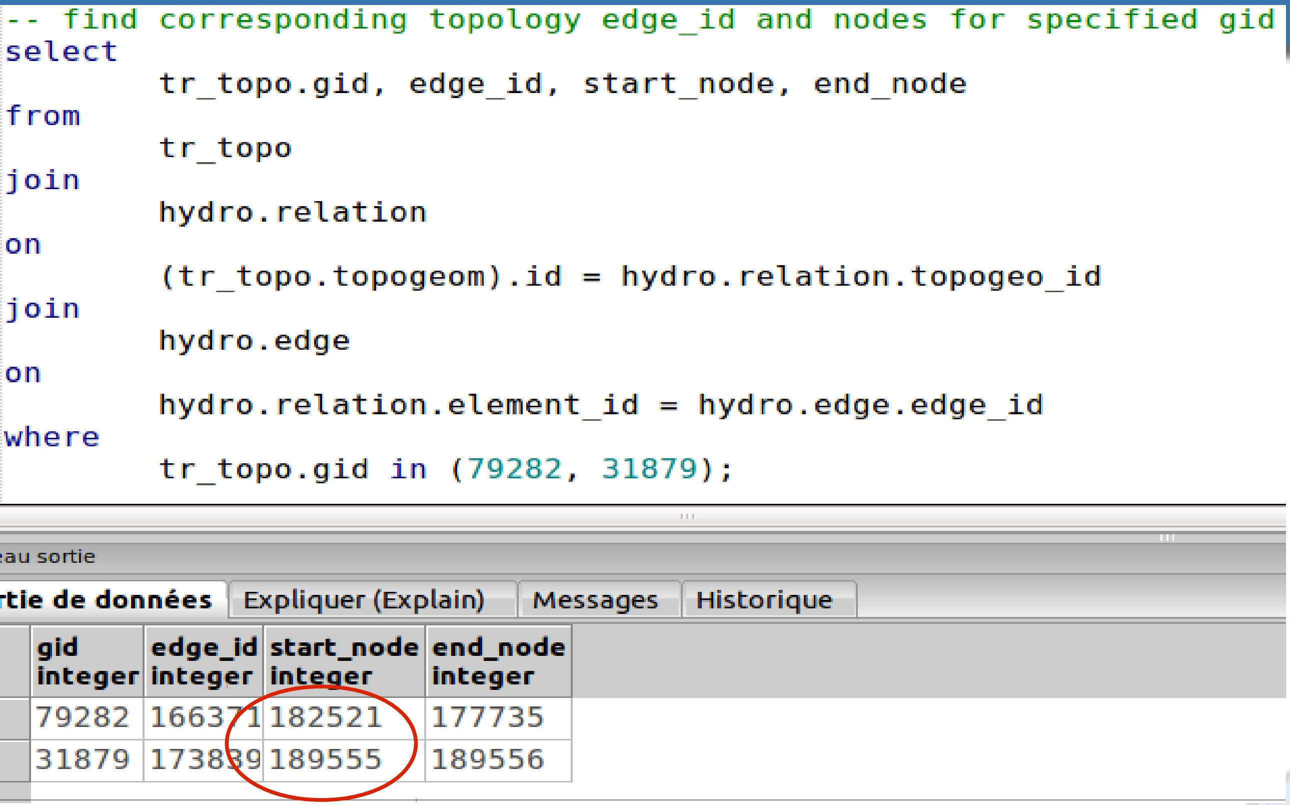
local-topo | id | the_geom | add layer

-492868.35,5477770.84 : 425199.46,5745540.62

Coordonnée : -125993,5642490

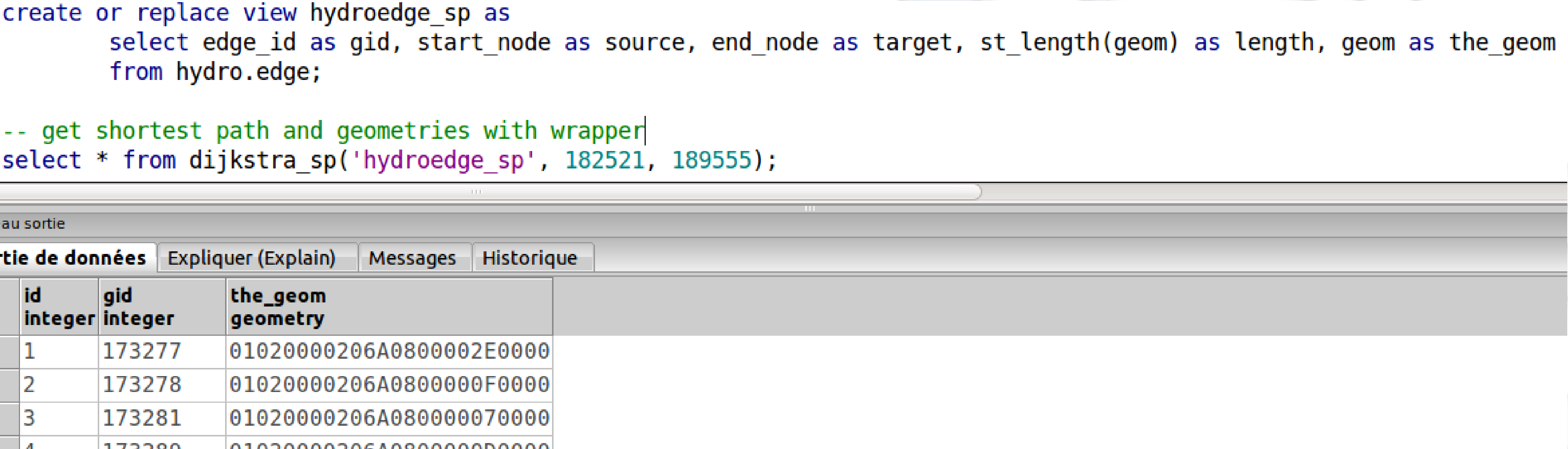
Échelle :1016276

PgRouting on PostGIS topology



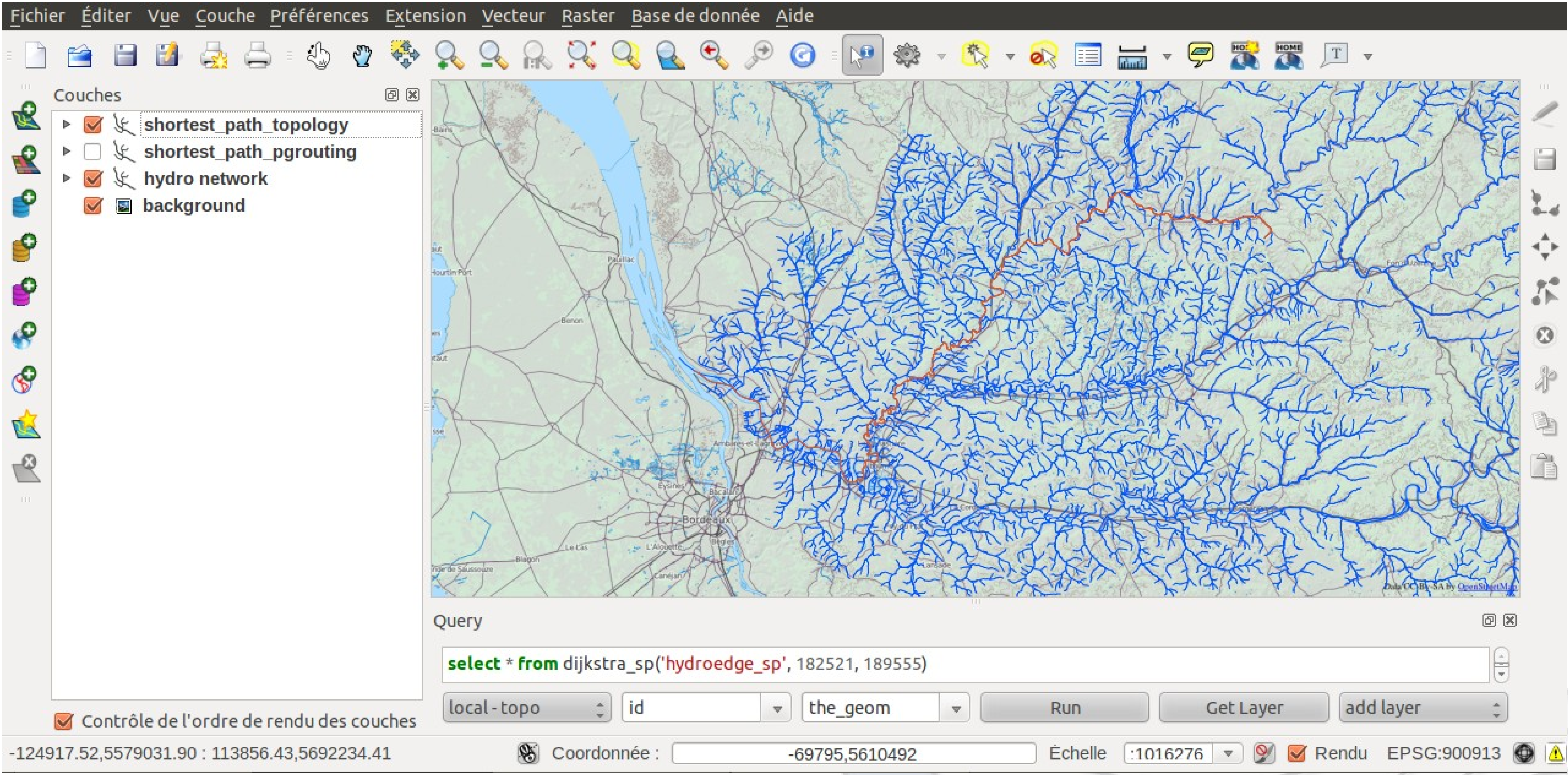
```
-- find corresponding topology edge_id and nodes for specified gid
select
        tr_topo.gid, edge_id, start_node, end_node
from
        tr_topo
join
        hydro.relation
on
        (tr_topo.topogeom).id = hydro.relation.topogeo_id
join
        hydro.edge
on
        hydro.relation.element_id = hydro.edge.edge_id
where
        tr_topo.gid in (79282, 31879);
```

gid integer	edge_id integer	start_node integer	end_node integer
79282	166371	182521	177735
31879	173839	189555	189556



```
create or replace view hydroedge_sp as
        select edge_id as gid, start_node as source, end_node as target, st_length(geom) as length, geom as the_geom
        from hydro.edge;

-- get shortest path and geometries with wrapper
select * from dijkstra_sp('hydroedge_sp', 182521, 189555);
```

id integer	gid integer	the_geom geometry
1	173277	01020000206A0800002E0000
2	173278	01020000206A0800000F0000
3	173281	01020000206A080000070000
4	173280	01020000206A0800000D0000



```
select * from dijkstra_sp('hydroedge_sp', 182521, 189555)
```

local-topo | id | the_geom | add layer

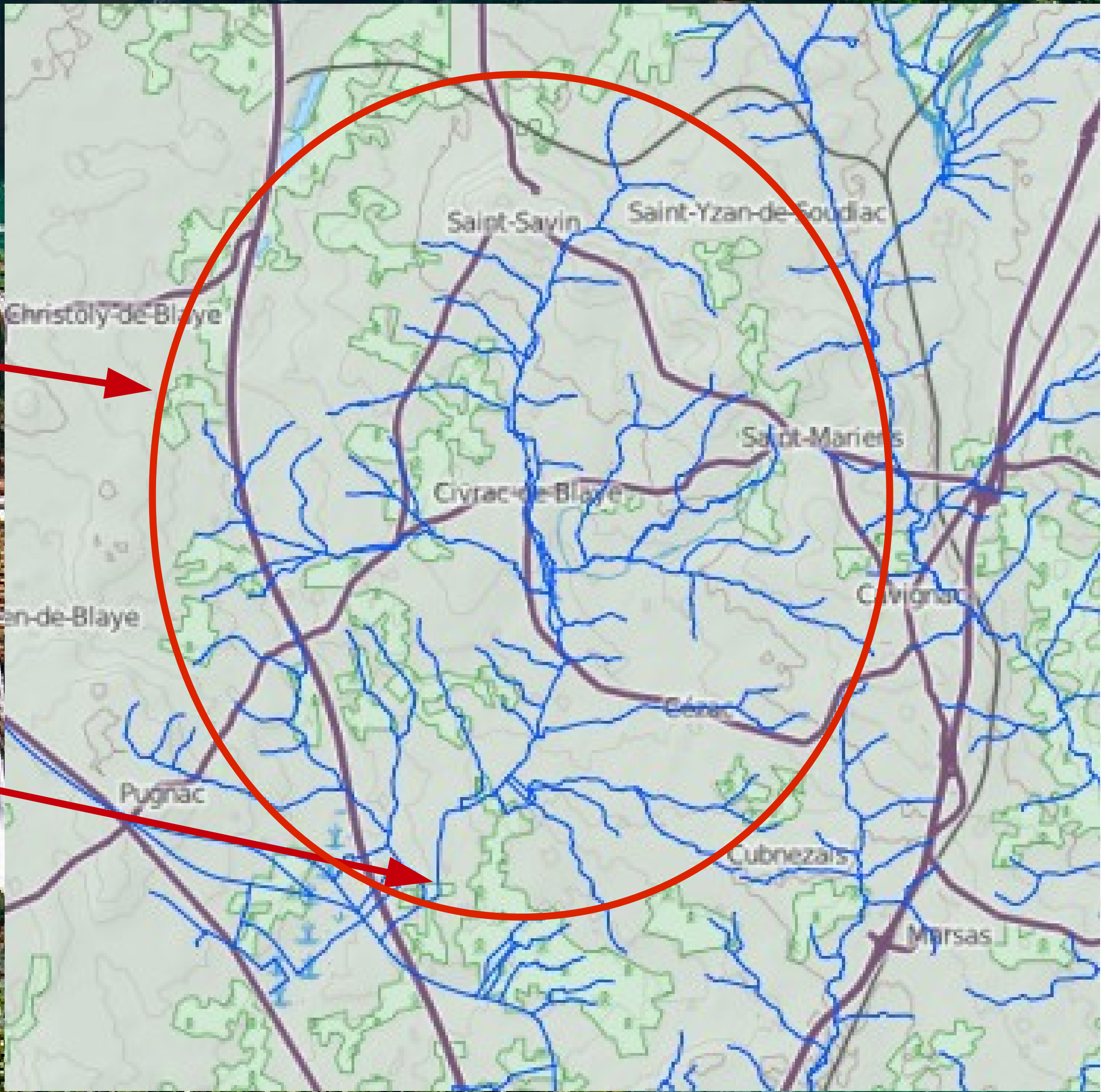
-124917.52,5579031.90 : 113856.43,5692234.41

Coordonnée : -69795,5610492

Échelle :1016276

☑ Rendu EPSG:900913

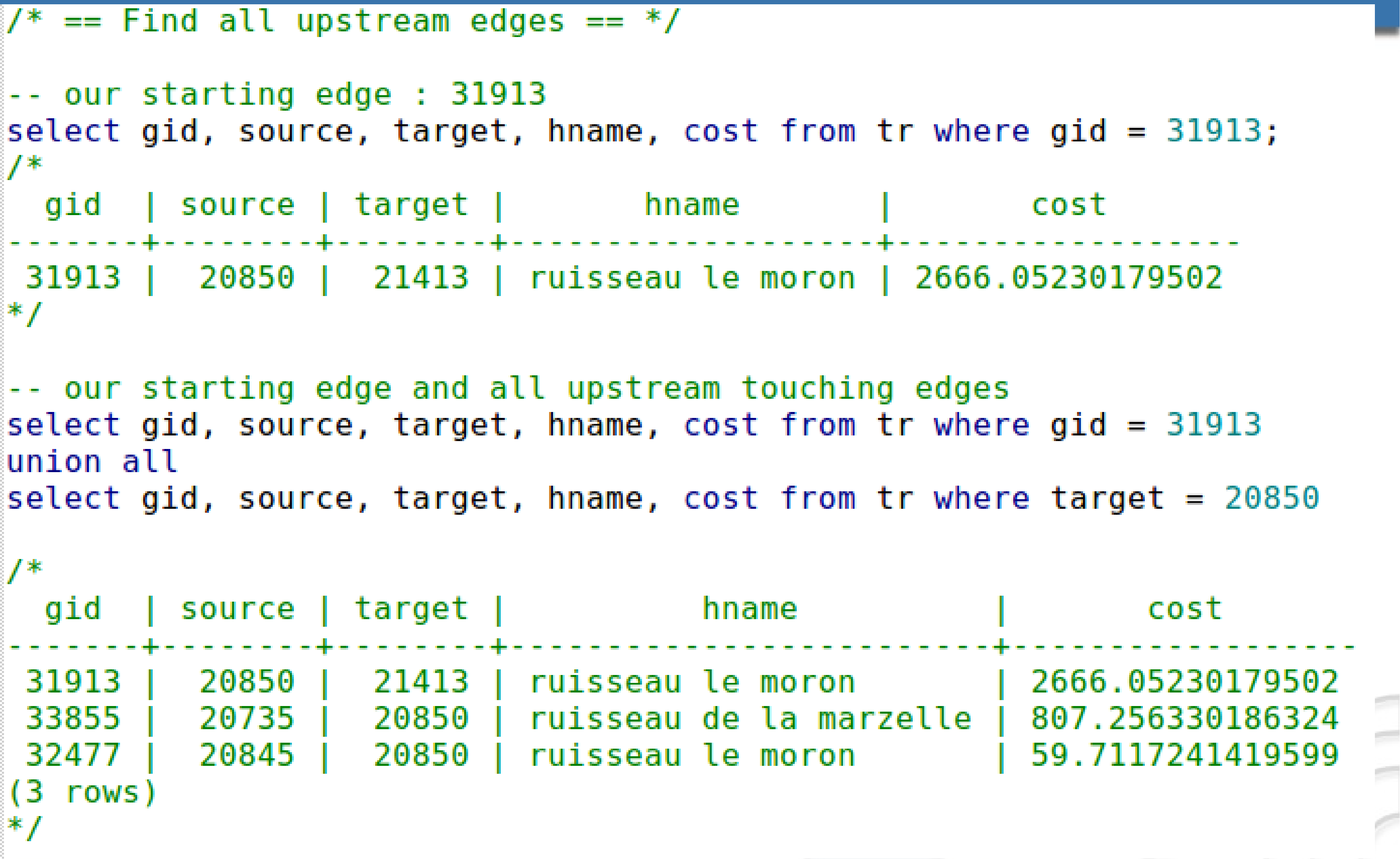
ind upstream



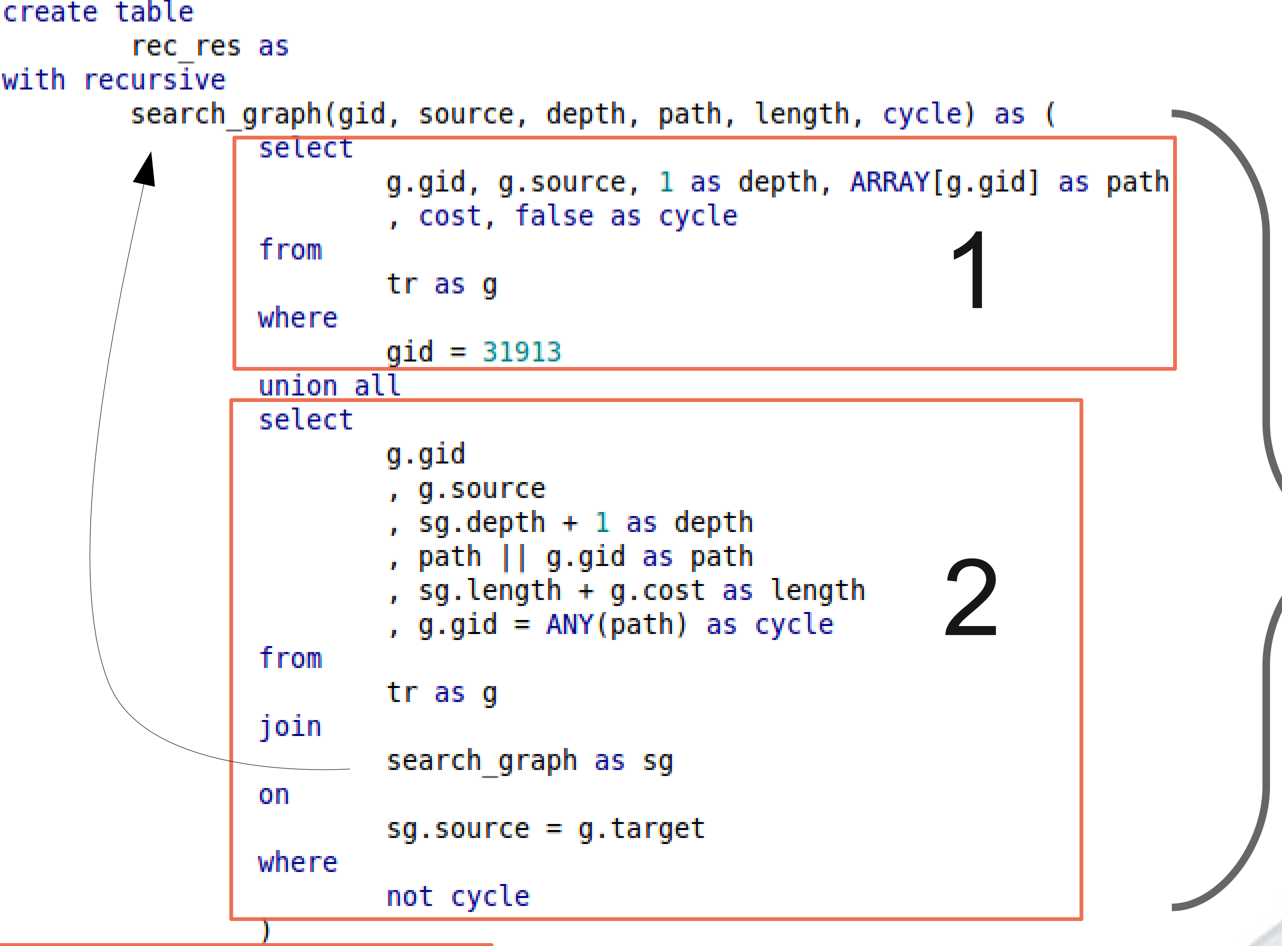
We want all connected edges upstream

Starting edge

Touching upstream edges

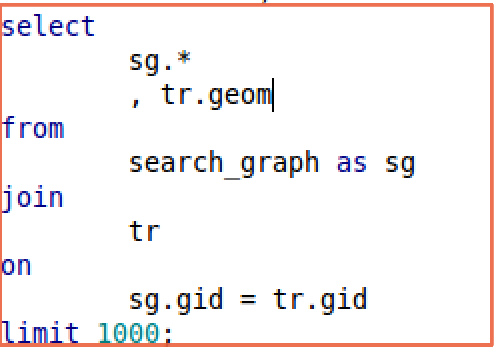


```
/* == Find all upstream edges == */

-- our starting edge : 31913
select gid, source, target, hname, cost from tr where gid = 31913;
/*
  gid  | source | target |       hname       |       cost
-------+--------+--------+-------------------+------------------
 31913 |  20850 |  21413 | ruisseau le moron | 2666.05230179502
*/

-- our starting edge and all upstream touching edges
select gid, source, target, hname, cost from tr where gid = 31913
union all
select gid, source, target, hname, cost from tr where target = 20850

/*
  gid  | source | target |          hname          |       cost
-------+--------+--------+-------------------------+------------------
 31913 |  20850 |  21413 | ruisseau le moron       | 2666.05230179502
 33855 |  20735 |  20850 | ruisseau de la marzelle | 807.256330186324
 32477 |  20845 |  20850 | ruisseau le moron       | 59.7117241419599
(3 rows)
*/
```



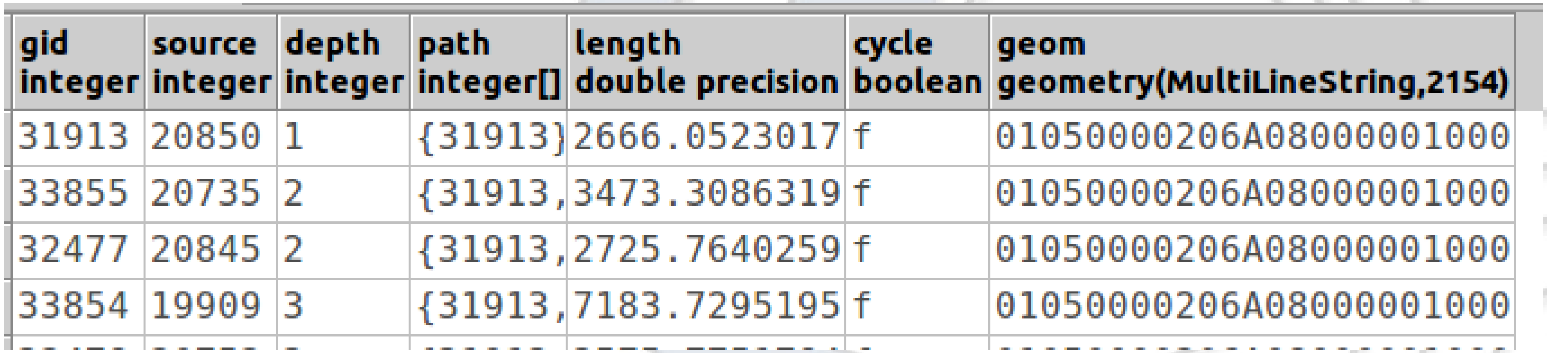
```
create table
        rec_res as
with recursive
        search_graph(gid, source, depth, path, length, cycle) as (
select
        g.gid, g.source, 1 as depth, ARRAY[g.gid] as path
        , cost, false as cycle
from
        tr as g
where
        gid = 31913
union all
select
        g.gid
        , g.source
        , sg.depth + 1 as depth
        , path || g.gid as path
        , sg.length + g.cost as length
        , g.gid = ANY(path) as cycle
from
        tr as g
join
        search_graph as sg
on
        sg.source = g.target
where
        not cycle
)
```

Recursive CTE



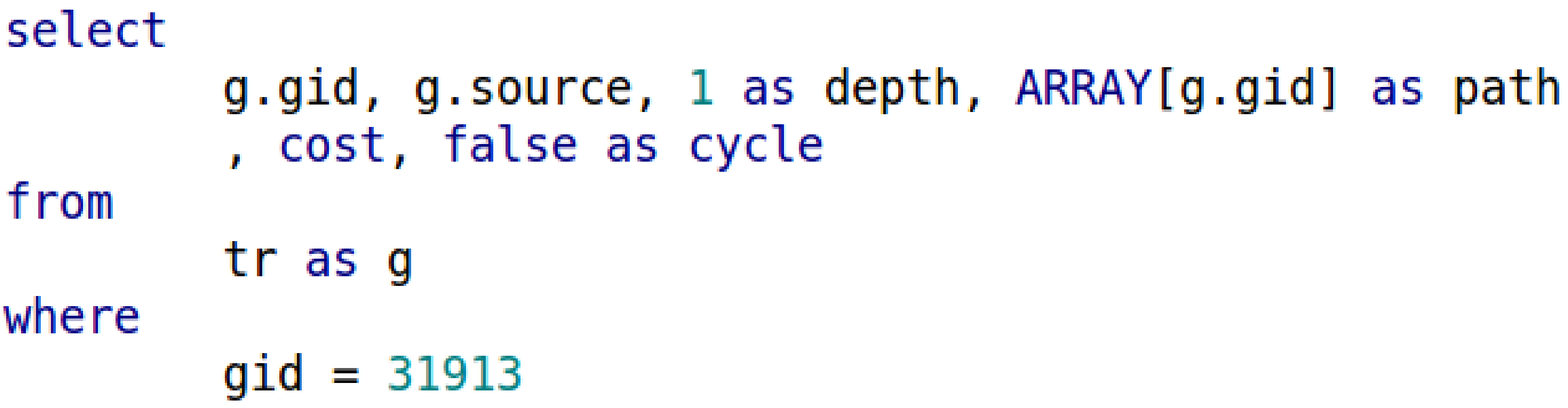
```
select
        sg.*
        , tr.geom
from
        search_graph as sg
join
        tr
on
        sg.gid = tr.gid
limit 1000;
```

3



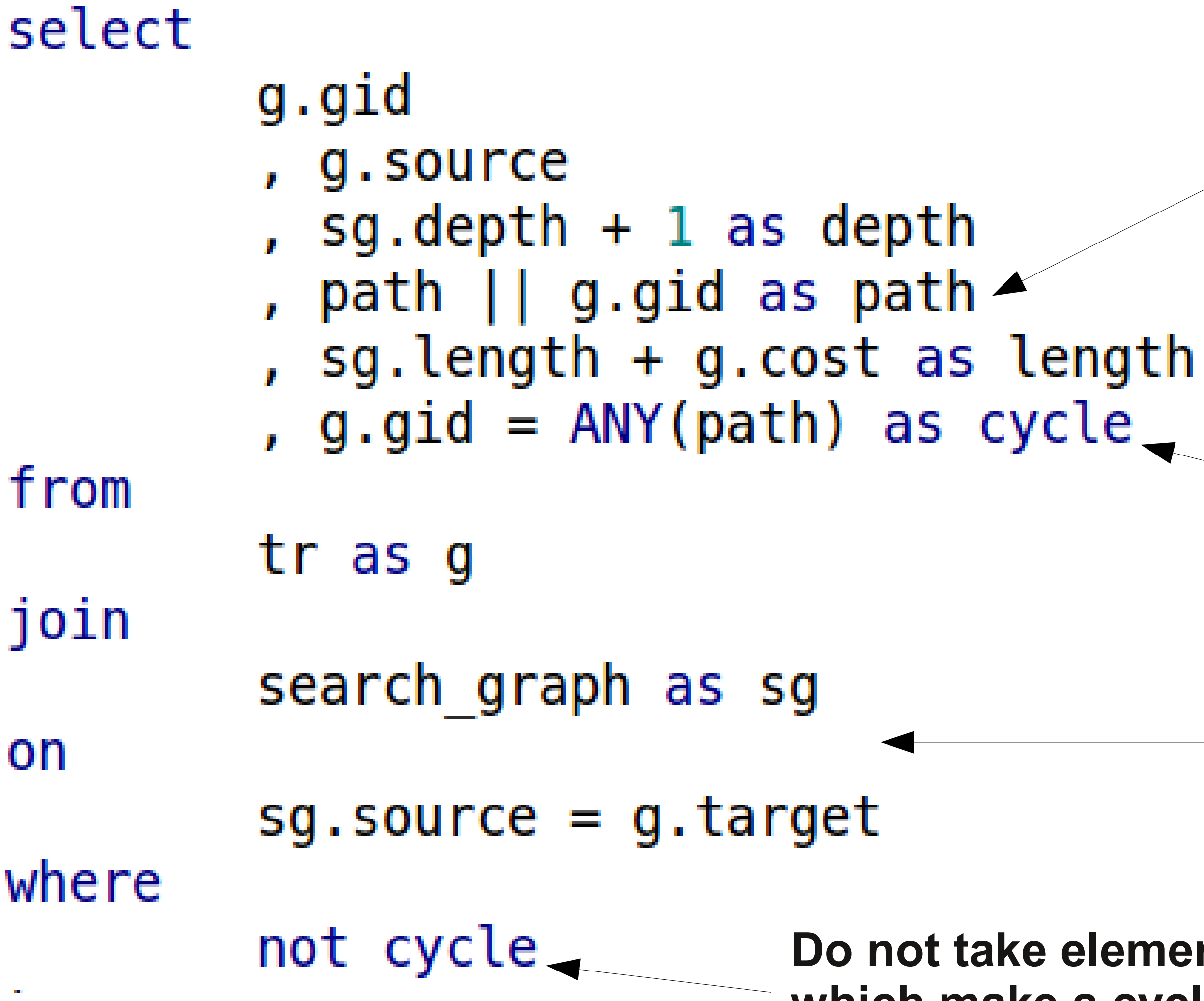
gid integer	source integer	depth integer	path integer[]	length double precision	cycle boolean	geom geometry(MultiLineString,2154)
31913	20850	1	{31913}	2666.0523017	f	01050000206A08000001000
33855	20735	2	{31913,	3473.3086319	f	01050000206A08000001000
32477	20845	2	{31913,	2725.7640259	f	01050000206A08000001000
33854	19909	3	{31913,	7183.7295195	f	01050000206A08000001000

1 : init



```
select
        g.gid, g.source, 1 as depth, ARRAY[g.gid] as path
        , cost, false as cycle
from
        tr as g
where
        gid = 31913
```

2 : recursive part



```
select
        g.gid
        , g.source
        , sg.depth + 1 as depth
        , path || g.gid as path
        , sg.length + g.cost as length
        , g.gid = ANY(path) as cycle
from
        tr as g
join
        search_graph as sg
on
        sg.source = g.target
where
        not cycle
```

Stack the gid to the path for this record

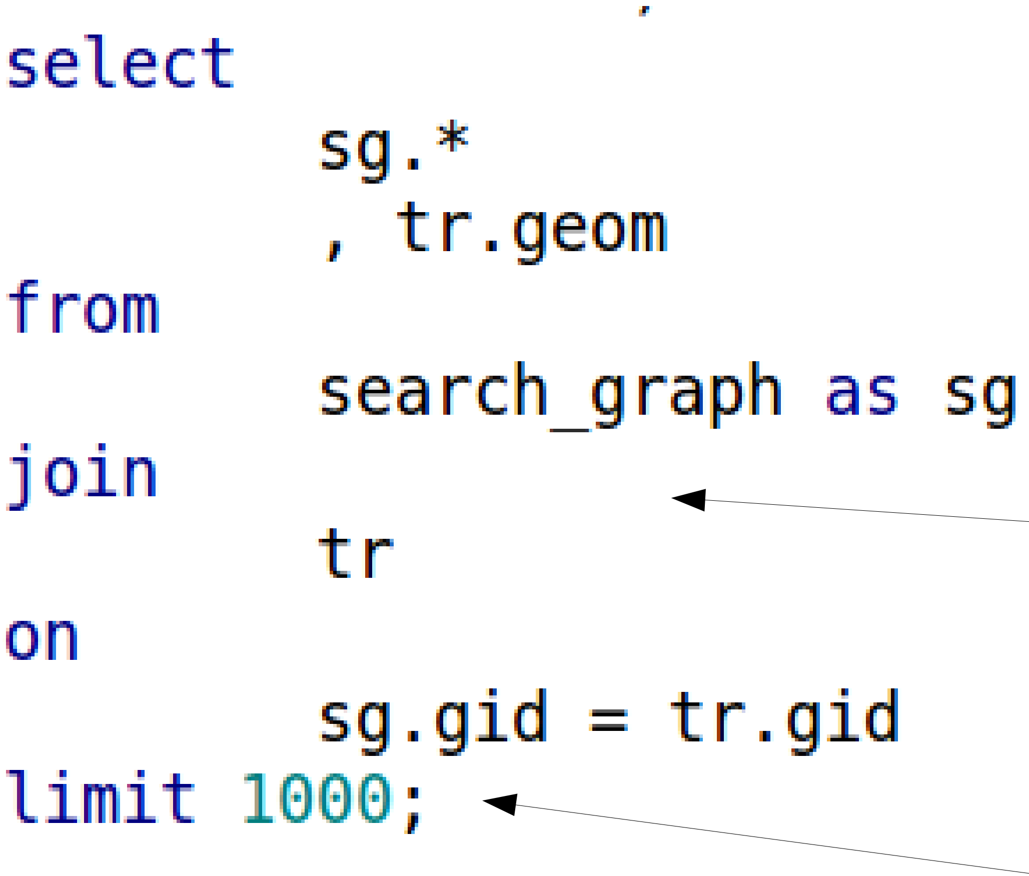
Sum up the cost (it's the length here)

If the record gid is already in the path, we have a cycle

Join result set from previous iteration to connected upstream edges

Do not take elements which make a cycle

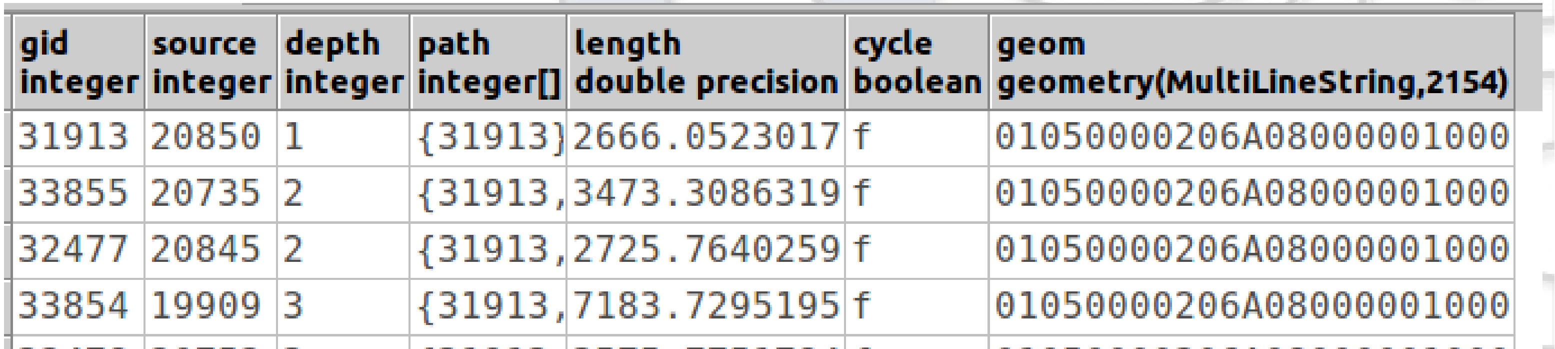
3 : Get results



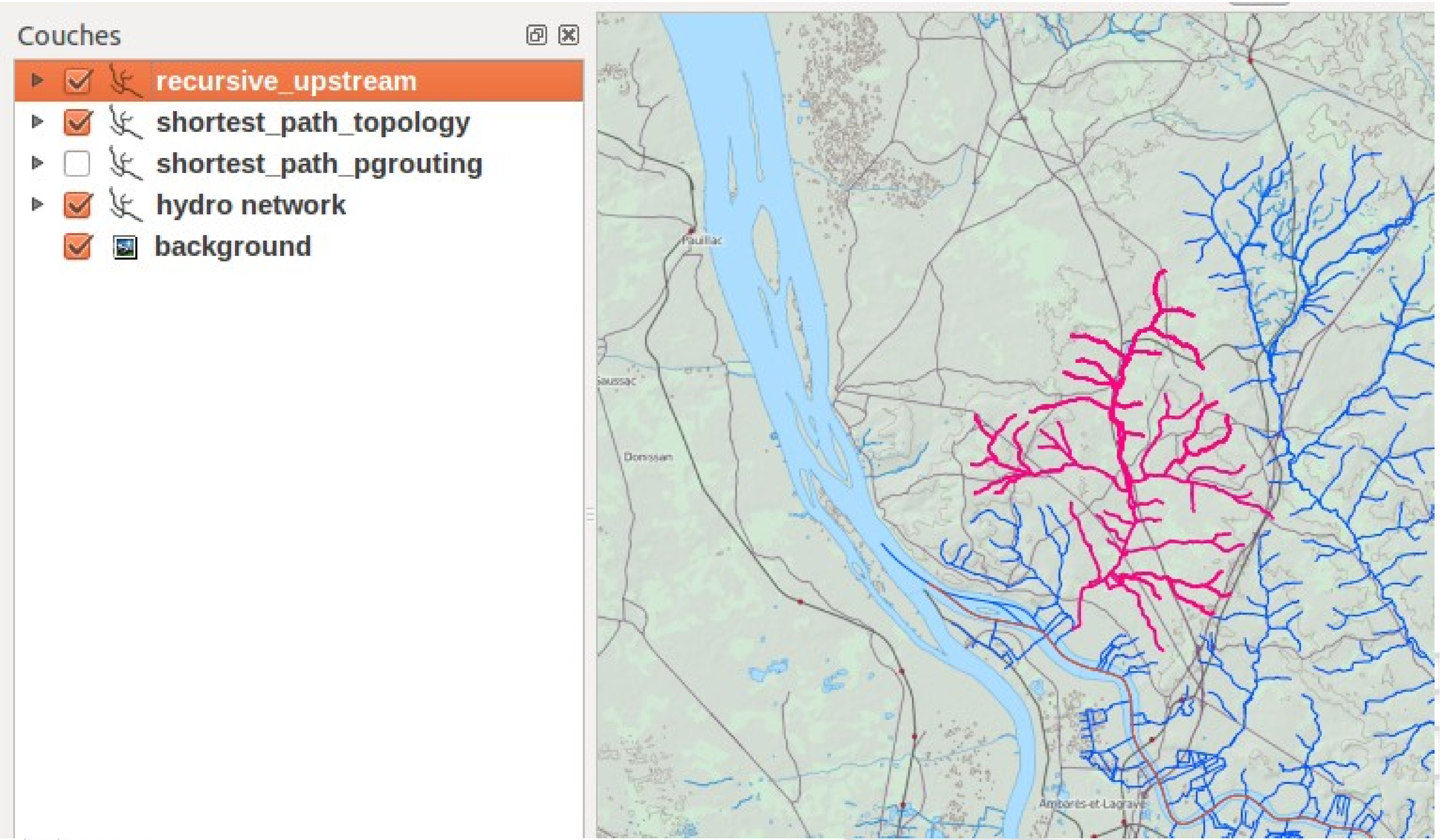
```
select
        sg.*
        , tr.geom
from
        search_graph as sg
join
        tr
on
        sg.gid = tr.gid
limit 1000;
```

Join CTE results to original table to get geometries

Better limit recursive queries to avoid unfinite loops



gid integer	source integer	depth integer	path integer[]	length double precision	cycle boolean	geom geometry(MultiLineString,2154)
31913	20850	1	{31913}	2666.0523017	f	01050000206A08000001000
33855	20735	2	{31913,	3473.3086319	f	01050000206A08000001000
32477	20845	2	{31913,	2725.7640259	f	01050000206A08000001000
33854	19909	3	{31913,	7183.7295195	f	01050000206A08000001000



Couches

- ☑ recursive_upstream
- ☑ shortest_path_topology
- □ shortest_path_pgrouting
- ☑ hydro network
- ☑ background

… and on PostGIS topology

1

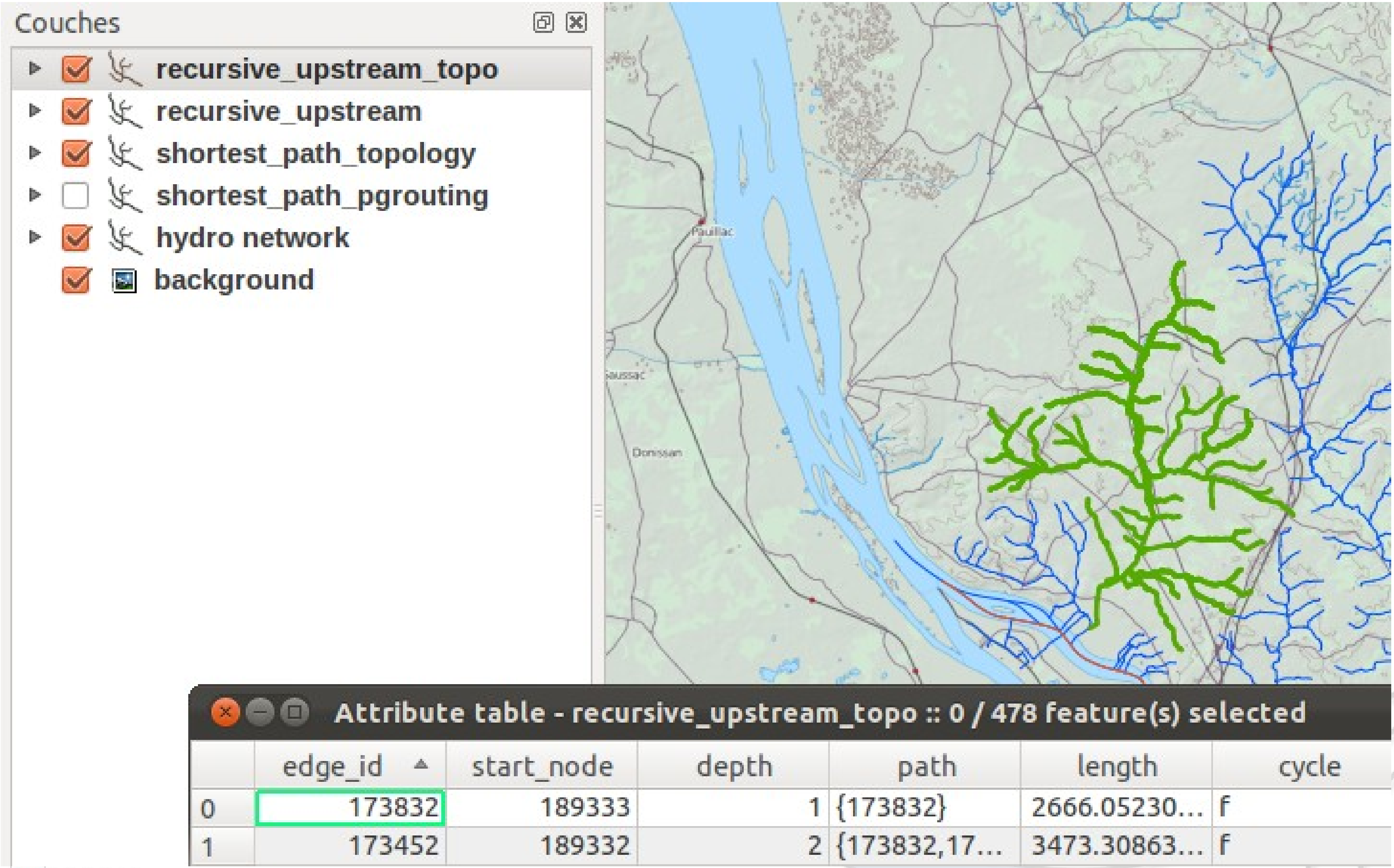
2

```
create table
        rec_res2 as
with recursive
        search_graph(edge_id, start_node, depth, path, length, cycle) as (
                select
                        g.edge_id, g.start_node, 1 as depth, ARRAY[g.edge_id] as path
                        , st_length(geom) as length, false as cycle
                from
                        hydro.edge as g
                where
                        edge_id = 173832
                union all
                select
                        g.edge_id
                        , g.start_node
                        , sg.depth + 1 as depth
                        , path || g.edge_id as path
                        , sg.length + st_length(g.geom) as length
                        , g.edge_id = ANY(path) as cycle
                from
                        hydro.edge as g
                join
                        search_graph as sg
                on
                        sg.start_node = g.end_node
                where
                        not cycle
                )
```

3

```
select
        sg.*
        , edge.geom as geom
from
        search_graph as sg
join
        hydro.edge as edge
on
        sg.edge_id = edge.edge_id
limit 1000;
```

OSLANDIA



Couches

- ▸ ☑ recursive_upstream_topo
- ▸ ☑ recursive_upstream
- ▸ ☑ shortest_path_topology
- ▸ □ shortest_path_pgrouting
- ▸ ☑ hydro network
- ☑ background

Attribute table - recursive_upstream_topo :: 0 / 478 feature(s) selected

	edge_id ▲	start_node	depth	path	length	cycle
0	173832	189333	1	{173832}	2666.05230…	f
1	173452	189332	2	{173832,17…	3473.30863…	f

Time out, brains washed, that's the end

Thanks !

http://2012.pgconf.eu/feedback

vincent.picavet@oslandia.com

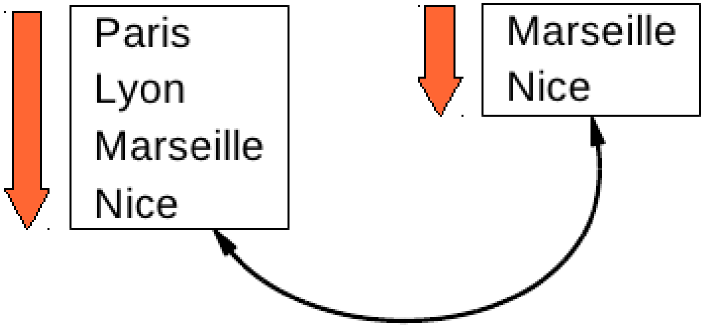
Twitter : @vpicavet

http://www.oslandia.com

BONUS SLIDES

GIS : use case

- Bisonvert.net
  - Car-sharing free software
- Goal
  - match people doing the same journey
- Current method
  - Match from/to via names



Paris
Lyon
Marseille
Nice

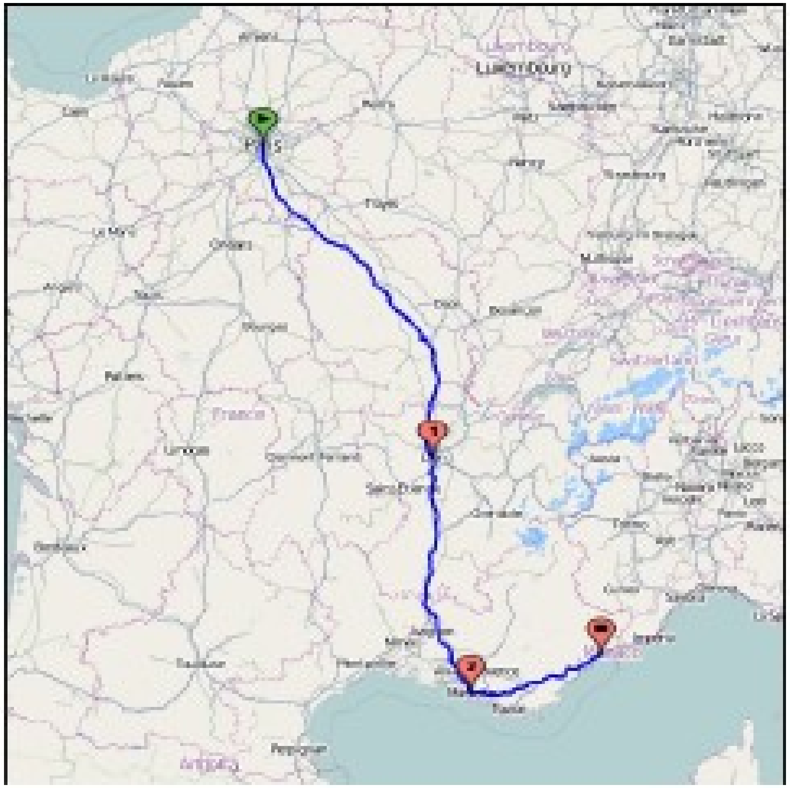
Marseille
Nice

GIS : use case

Solution :

Use real paths

- 1/ Compute path (routing)
- 2/ Match paths
  (Spatial analysis)


Luxembourg
France
Paris