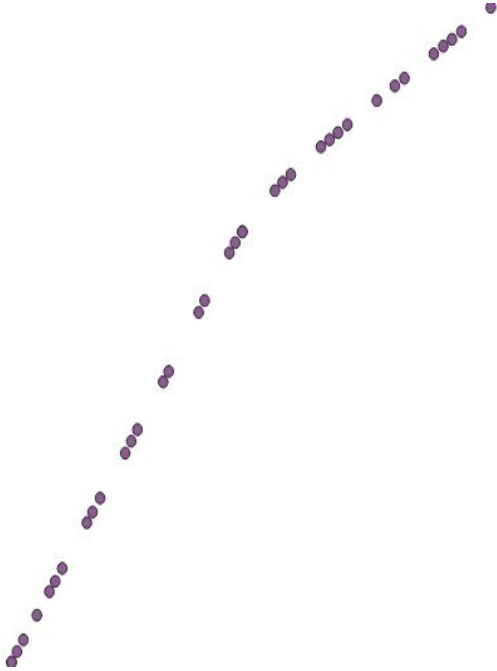




# Trajectory Data Management Using MobilityDB

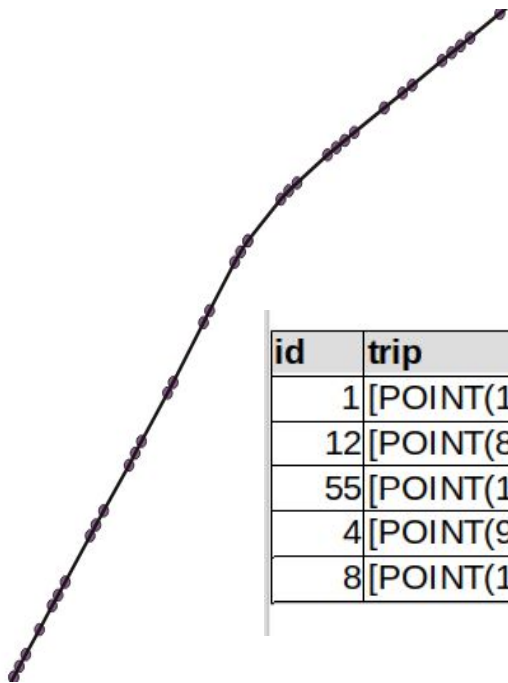
Contact: Esteban Zimanyi (ezimanyi@ulb.ac.be)  
Mahmoud SAKR (mahmoud.sakr@ulb.ac.be)

# Mobility Data: PostGIS



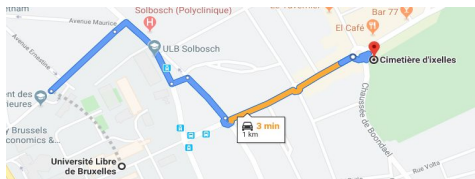
id	geom	t
1	POINT(15.839728 55.836783)	2018-04-01 19:34:49+00
1	POINT(15.831427 55.83403)	2018-04-01 19:36:19+00
1	POINT(15.823145 55.831307)	2018-04-01 19:37:49+00
1	POINT(15.820398 55.830398)	2018-04-01 19:38:19+00
1	POINT(15.817642 55.829467)	2018-04-01 19:38:49+00
1	POINT(15.816722 55.829165)	2018-04-01 19:38:59+00
1	POINT(15.814793 55.828537)	2018-04-01 19:39:20+00
1	POINT(15.80575 55.825483)	2018-04-01 19:40:59+00
1	POINT(15.798323 55.823005)	2018-04-01 19:42:20+00
1	POINT(15.797487 55.822735)	2018-04-01 19:42:29+00
1	POINT(15.792805 55.821195)	2018-04-01 19:43:20+00
1	POINT(15.791978 55.820913)	2018-04-01 19:43:29+00
1	POINT(15.786472 55.81908)	2018-04-01 19:44:29+00
1	POINT(15.784457 55.818405)	2018-04-01 19:44:50+00
1	POINT(15.779068 55.816605)	2018-04-01 19:45:50+00
1	POINT(15.776327 55.815688)	2018-04-01 19:46:20+00
1	POINT(15.775412 55.815377)	2018-04-01 19:46:29+00
1	POINT(15.774503 55.815063)	2018-04-01 19:46:39+00
1	POINT(15.772762 55.814488)	2018-04-01 19:46:59+00
1	POINT(15.770842 55.813838)	2018-04-01 19:47:20+00
1	POINT(15.76726 55.812655)	2018-04-01 19:47:59+00
1	POINT(15.764525 55.811742)	2018-04-01 19:48:29+00

# Mobility Data: Trajectories



id	trip
1	[POINT(15.839728 55.836783)@2018-04-01 19:34:49+00, POINT(15.831427 55.83403)@2018-
12	[POINT(8.067513 57.851652)@2018-04-01 07:35:06+00, POINT(8.073813 57.848518)@2018-
55	[POINT(12.446722 54.689387)@2018-04-01 00:00:00+00, POINT(12.447155 54.689822)@201
4	[POINT(9.752845 55.544552)@2018-04-01 08:34:16+00, POINT(9.75391 55.545305)@2018-0
8	[POINT(10.141707 55.152783)@2018-04-01 07:11:16+00, POINT(10.141707 55.152783)@201

# MobilityDB




MobilityDB

tgeompoint, tgeogpoint,  
tint, tfloat, ttext, tbool

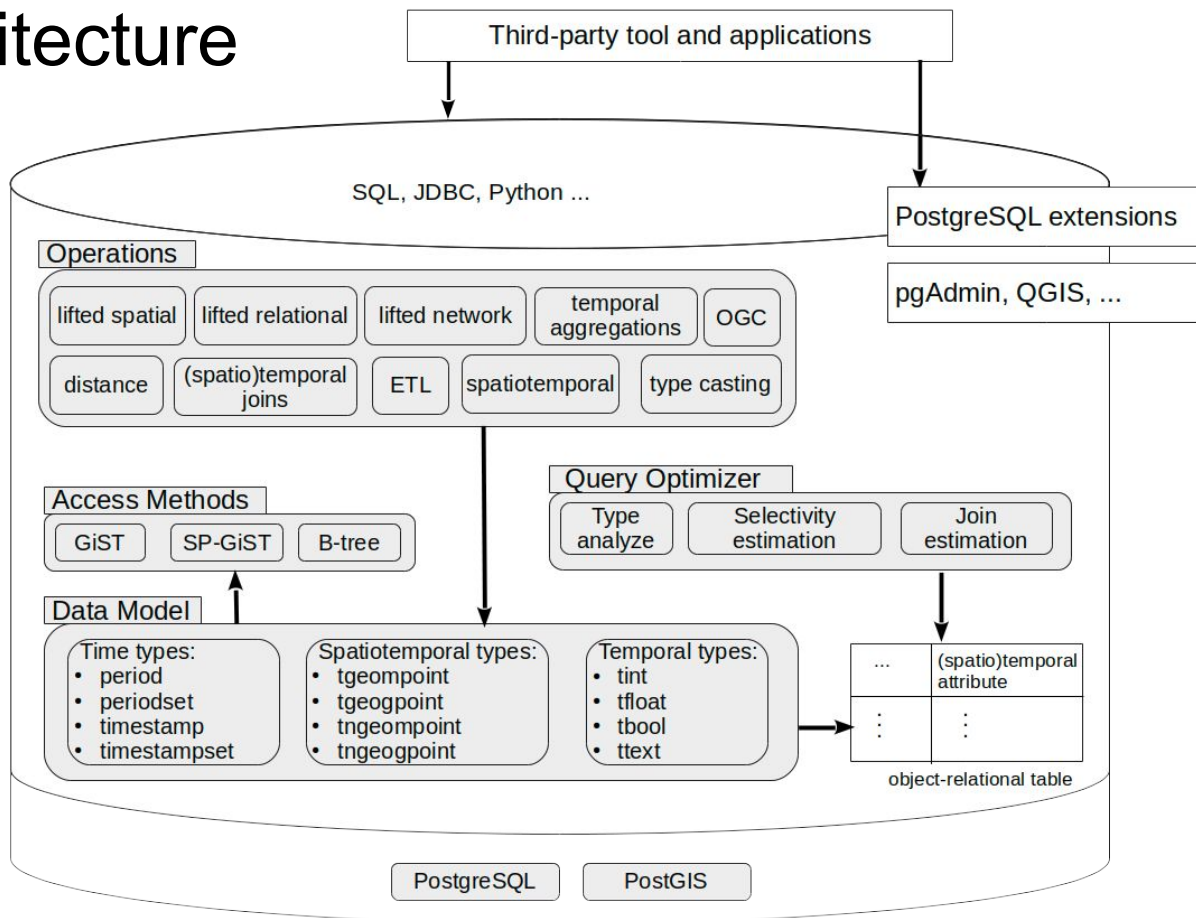
PostGIS

geometry, geography














PostgreSQL

numeric, monetary, character,  
data/time, boolean, enum,  
arrays, range,  
XML, JSON, ...

# MobilityDB Architecture



# MobilityDB Ecosystem

MobilityDB MapMatch		MobilityDB Exchange		MobilityDB View		MobilityDB ETL	
MobilityDB Distributed	MobilityDB Network	MobilityDB Stream		python- mobilitydb	MobilityDB JDBC		
				asyncpg			
							
							

# Loading Data: CSV Example

```
CREATE EXTENSION MobilityDB CASCADE;
```

```
CREATE TABLE TripsInput (  
  CarId integer REFERENCES Cars,  
  TripId integer,  
  Lon float,  
  Lat float,  
  T timestamptz,  
  PRIMARY KEY (CarId, TripId, T) );
```

```
CREATE TABLE Trips (  
  CarId integer NOT NULL,  
  TripId integer NOT NULL,  
  Trip tgeompoint,  
  PRIMARY KEY (CarId, TripId),  
  FOREIGN KEY (CarId)  
    REFERENCES Cars (CarId) );
```

```
INSERT INTO Trips  
  SELECT CarId, TripId,  
    tgeompointseq(array_agg(tgeompointinst(  
      ST_Transform(ST_SetSRID(ST_MakePoint(Lon,Lat), 4326), 5676), T) ORDER BY T))  
  FROM TripsInput  
  GROUP BY CarId, TripId;
```

# Loading Data: GTFS Example

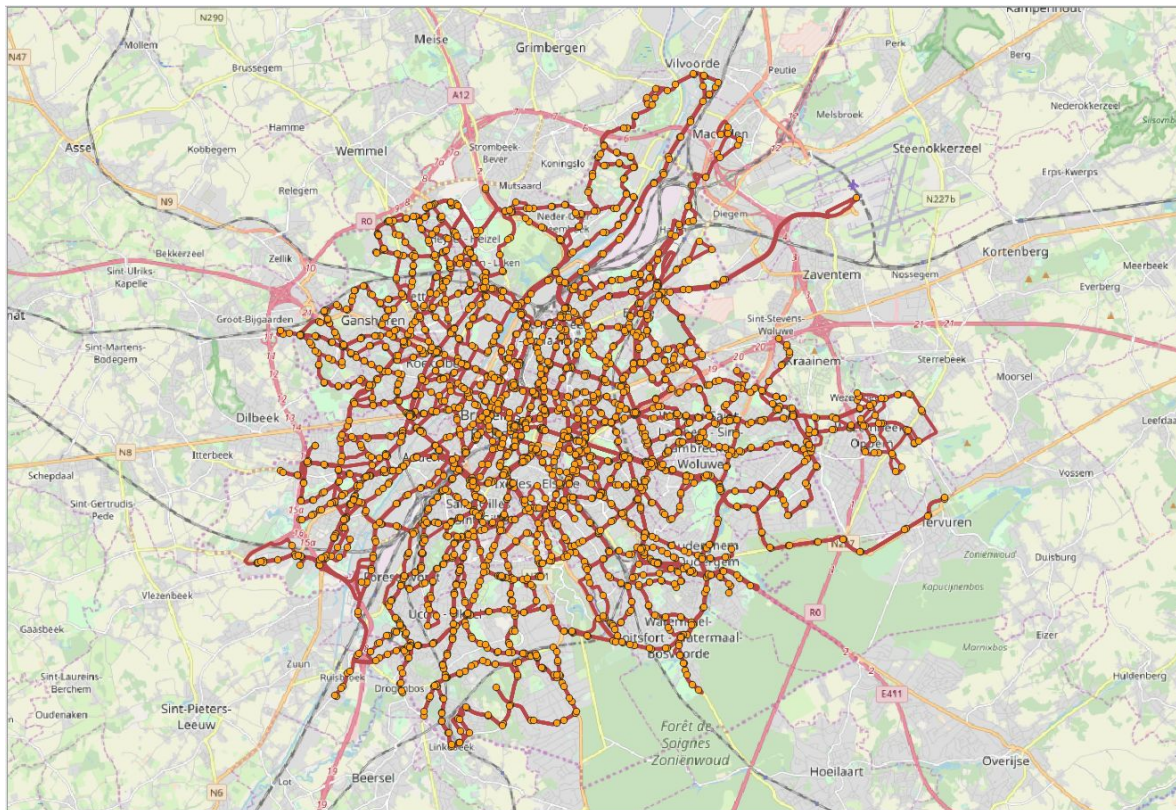
**Source:** STIB, Brussels

**Duration:** 28 days

7 Oct- 3 Nov 2019

**#Trips:** 445,187

**DB size:** 9 GB



# Loading Data: Google Location Data

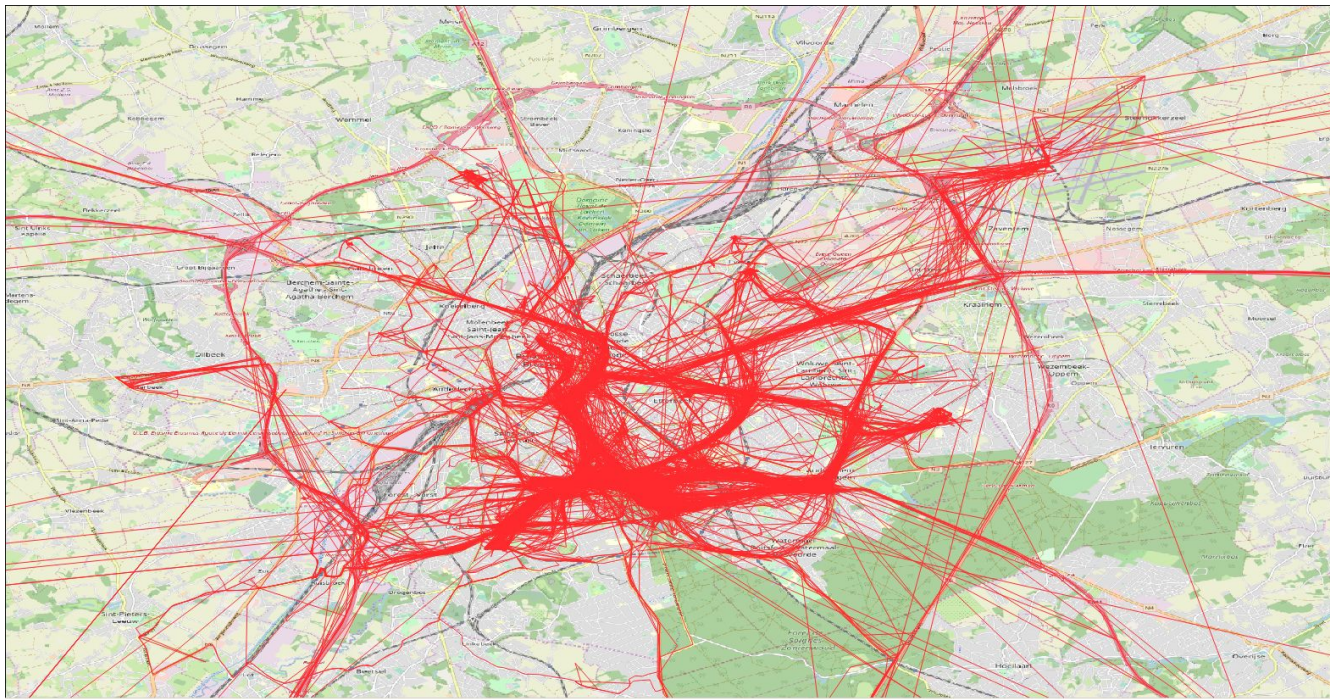
**Source:** Personal  
Google data

**Duration:** 6 years  
with time gaps

**JSON size:** 144 MB

**CSV size:** 8 MB  
converted with jq

**#Trips:** One per day



# Loading Data: Maritime Data (AIS)

**Source:** Danish Maritime Authority

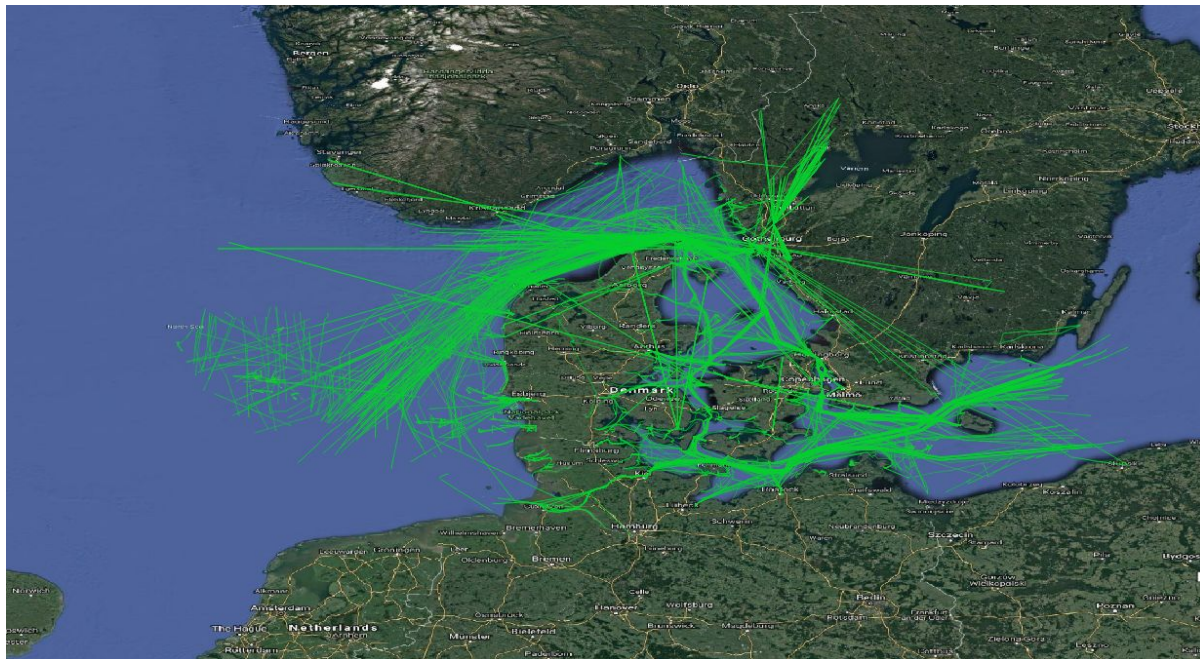
**Duration:** one day

April 1st 2018

**#Rows:** 10M

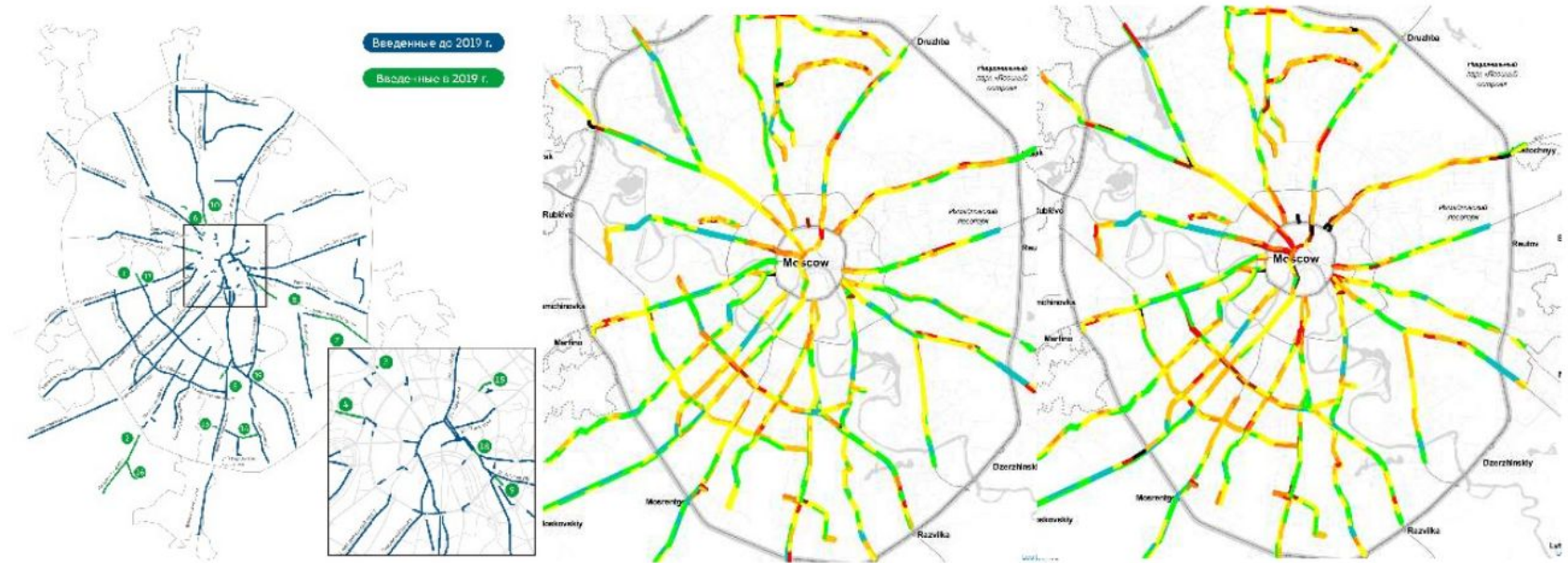
**#Trips:** 2,995

**DB size:** 1 GB



# Data analysis - velocity maps

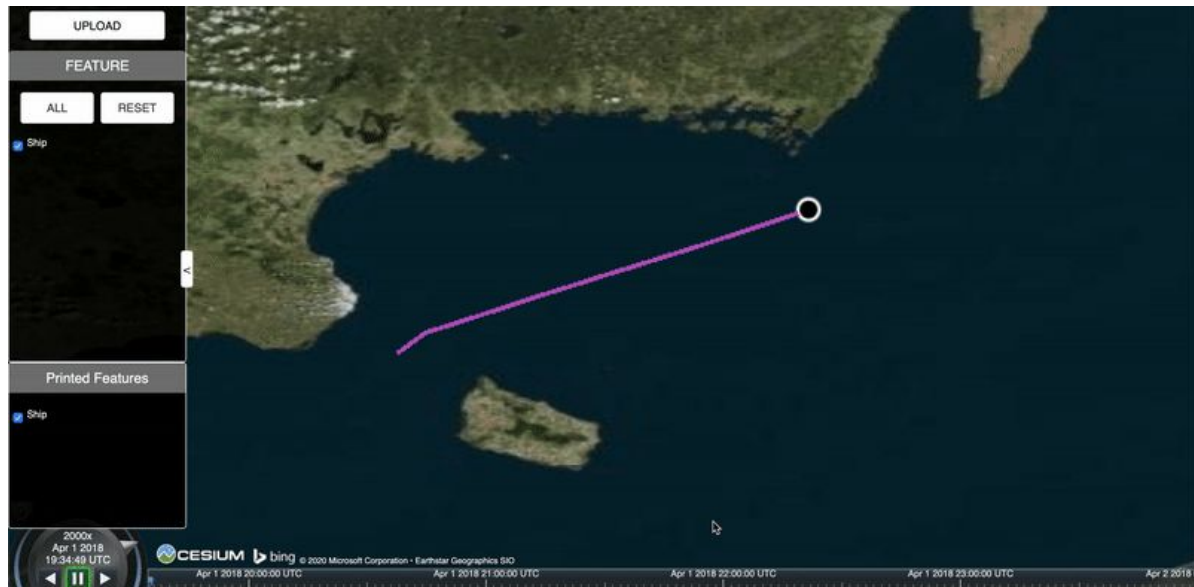
## Moscow bus lanes



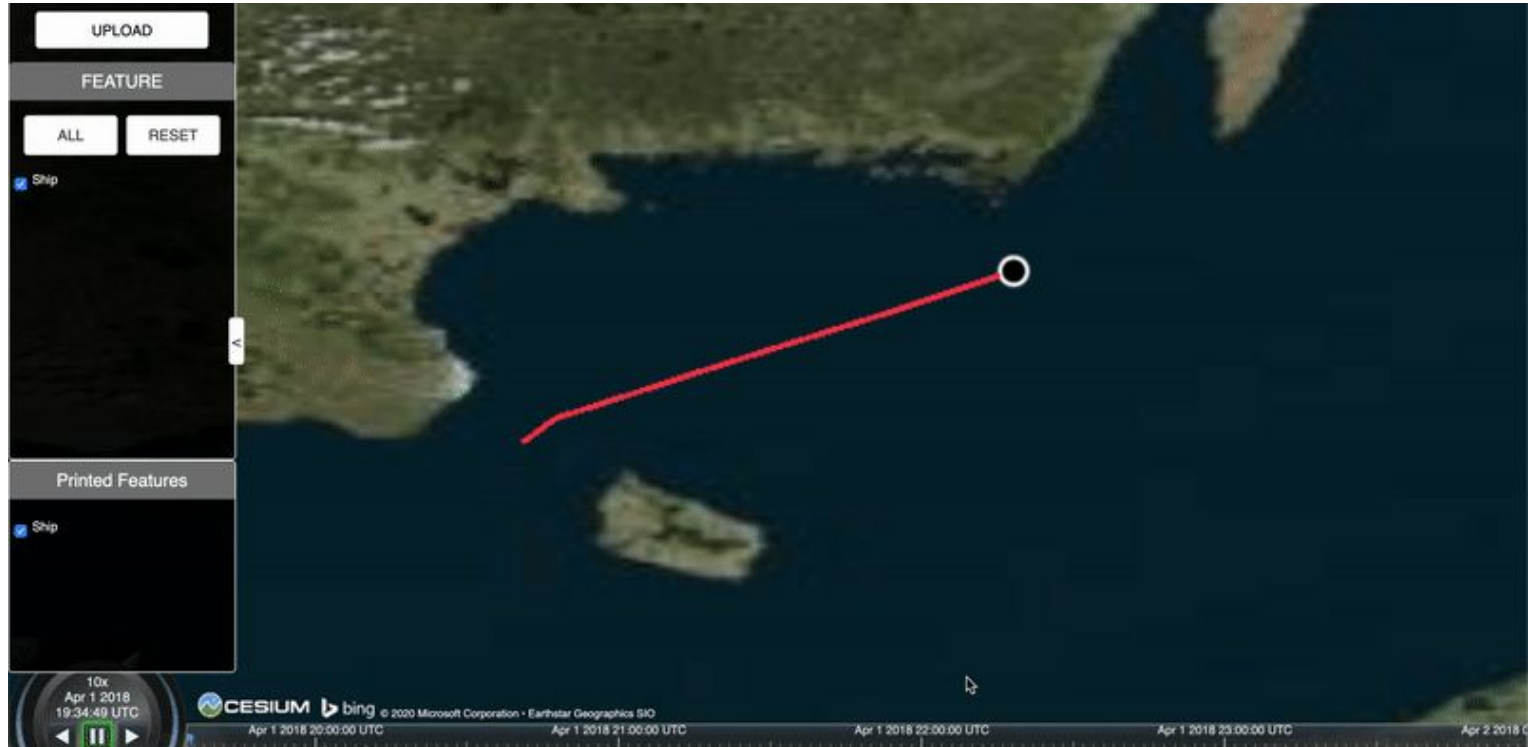
# Visualization - Cesium MF-JSON

Cesium extension for  
MF-JSON visualization.

Kyoung-Sook KIM et al.,  
Artificial Intelligence  
Research Center (AIRC) of  
AIST in Japan.



# Visualization - Cesium MF-JSON



# Quick Example: Spatial Projection

```
TABLE Ships(mmsi integer, trip tgeompoint, sog tfloat, cog tfloat, traj  
geometry, tripETRS tgeompoint )
```

List the ships that commute between the ports Rødby and Puttgarden.

```
CREATE INDEX Ships_tripETRS_idx ON Ships USING GiST(tripETRS);
```

```
SELECT *  
FROM Ships  
WHERE intersects( tripETRS, ST_MakeEnvelope(...) ) AND  
       intersects( tripETRS, ST_MakeEnvelope(...) )
```

The intersects function is index supported, i.e.,



# Quick Example: Temporal Operations

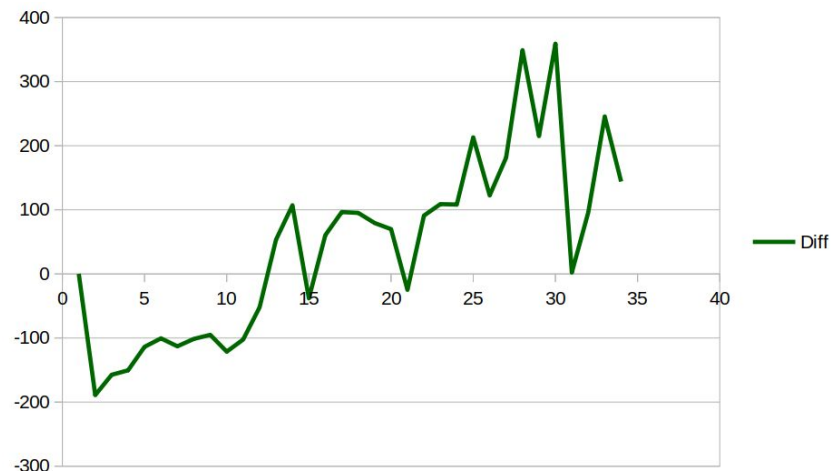
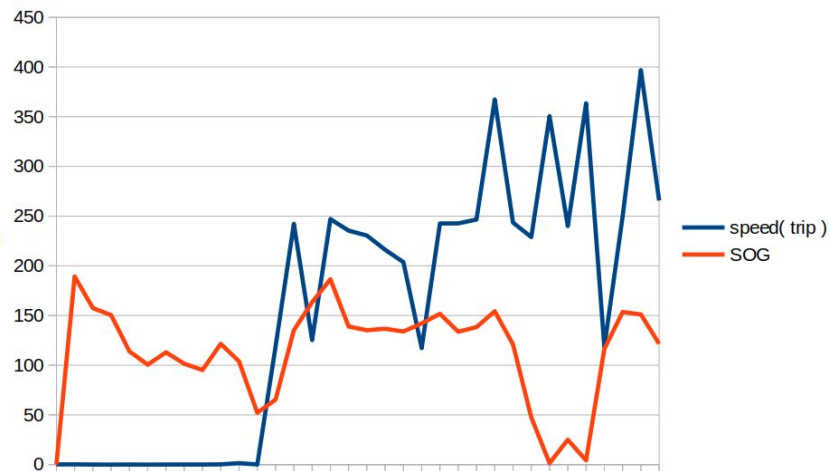
```
TABLE Ships(mmsi integer, trip tgeompoint, sog tfloat, cog tfloat, traj  
geometry, tripETRS tgeompoint )
```

Find all the trips that report SOG very different from the speed calculated from their trajectories (noise, broken sensor, ...).

```
SELECT *  
FROM Ships  
WHERE twavg ( ( speed( tripETRS ) * 3.6 ) - ( sog * 1.852 ) ) > 10
```

# Quick Example: Temporal Operations

```
SELECT *  
FROM Ships  
WHERE twavg ( ( speed( tripETRS ) * 3.6 ) - ( sog * 1.852 ) ) > 10
```



# Quick Example: Aggregation

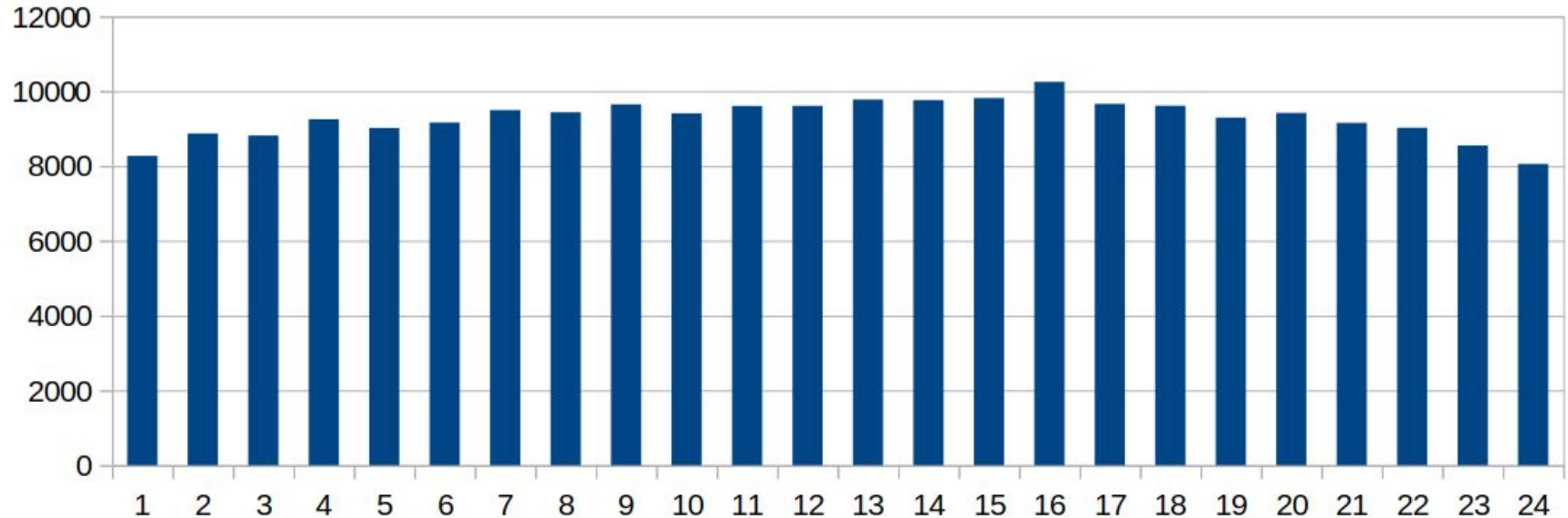
```
TABLE Ships(mmsi integer, trip tgeompoint, sog tfloat, cog tfloat, traj
geometry, tripETRS tgeompoint )
```

What is the total distance travelled by ships per hour

```
WITH TimeSplit(Period) AS (
    SELECT period(H, H + interval '1 hour')
    FROM generate_series(timestamptz '2018-04-01 00:00:00',
        timestamptz '2018-04-02 00:00:00', interval '1 hour') AS H )
SELECT Period, SUM( length( atPeriod( TripETRS, Period) ) )/1000 travelledKms
FROM TimeSplit T, Ships S
WHERE T.Period && S.Trip
GROUP BY T.Period
ORDER BY T.Period;
```

# Quick Example: Aggregation

What is the total distance travelled by ships per hour

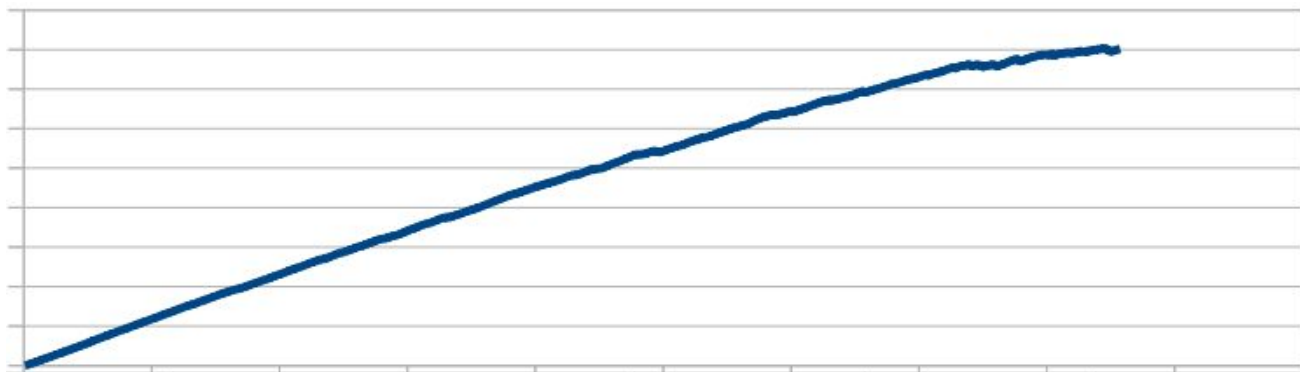


# Quick Example: Temporal Aggregation

```
TABLE Ships(mmsi integer, trip tgeompoint, sog tfloat, cog tfloat, traj  
geometry, tripETRS tgeompoint )
```

What is the cumulative distance travelled by the company busses at each instant during one week.

```
SELECT tsum( cumulativeLength( TripETRS ) ) traveled  
FROM Ships;
```

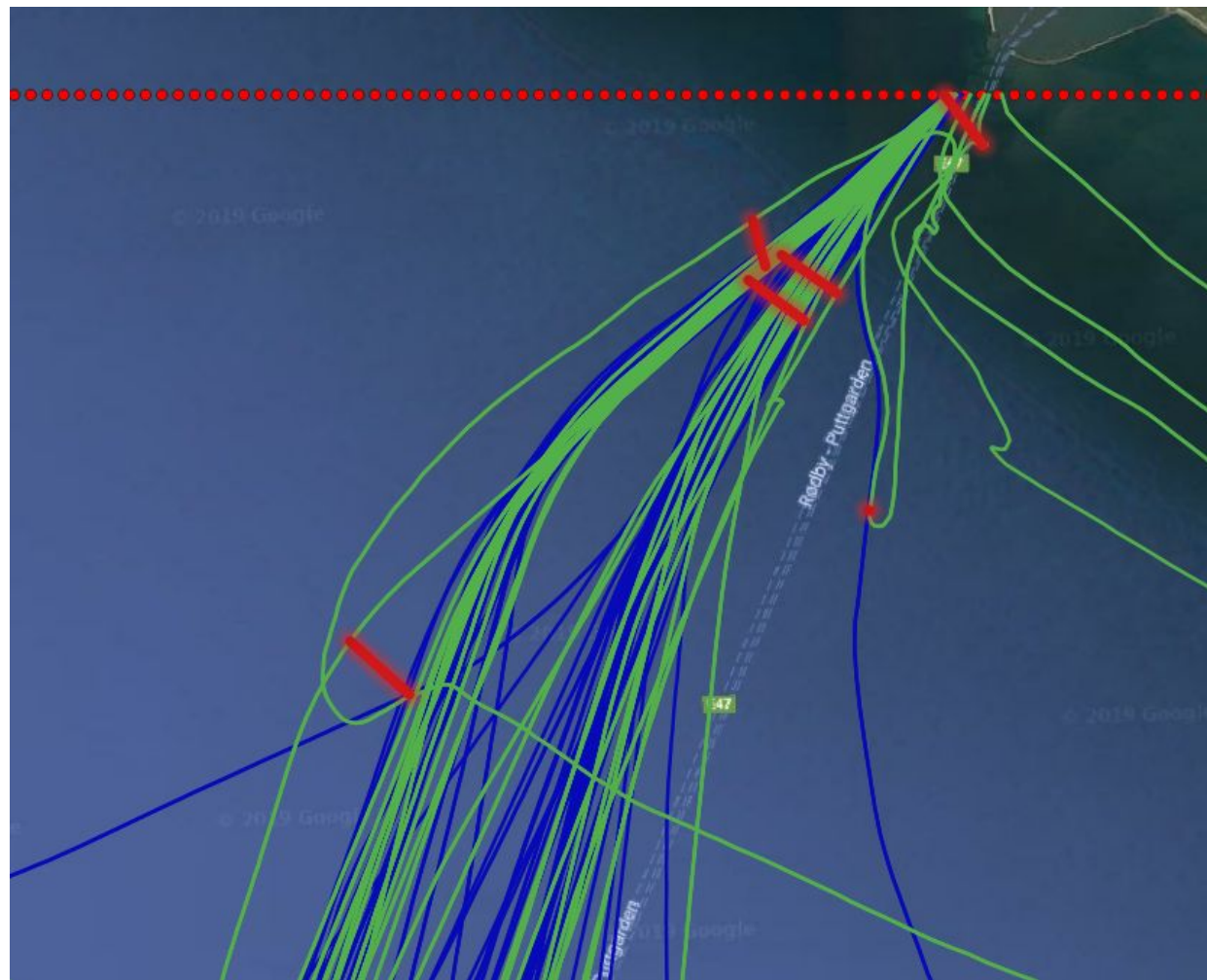


# Quick Example: Spatiotemporal Join

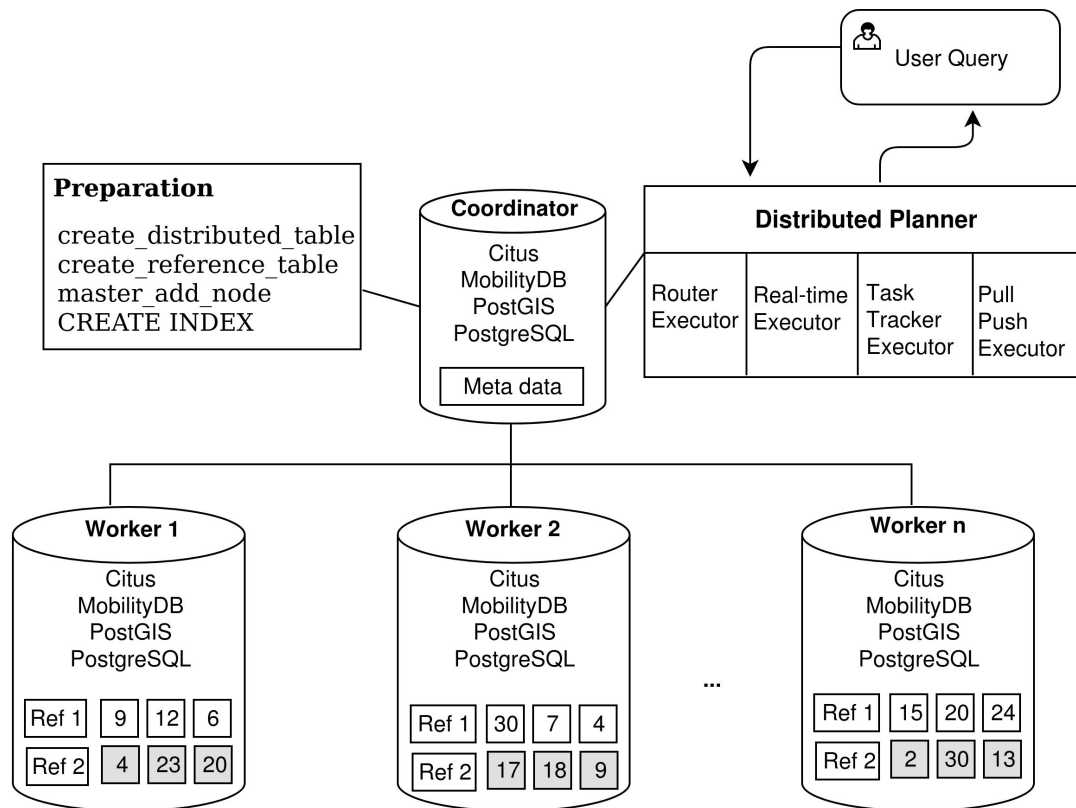
```
TABLE Ships(mmsi integer, trip tgeompoint, sog tfloat, cog tfloat, traj  
geometry, tripETRS tgeompoint )
```

Ships that come closer than 300 meters to one another.

```
SELECT S1.MMSI, S2.MMSI, S1.Traj, S2.Traj,  
       shortestLine(S1.tripETRS, S2.tripETRS) Approach  
FROM Ships S1, Ships S2  
WHERE S1.MMSI > S2.MMSI AND  
       dwithin(S1.tripETRS, S2.tripETRS, 300)
```



# Distributed MobilityDB Using Citus





# MobilityDB

- A moving object database MOD
- Builds on PostgreSQL and PostGIS
- Developed by a team in Université libre de Bruxelles
- OPEN SOURCE extension
- Compliant with OGC standards on Moving Features, and in particular the OGC Moving Features Access




# MobilityDB on Github

GitHub - ULB-CoDE-WIT/MobilityDB

github.com/ULB-CoDE-WIT/MobilityDB

build passing coverage 96%

## MobilityDB



MobilityDB is an open source software program that adds support for temporal and spatio-temporal objects to the [PostgreSQL](#) object-relational database and its spatial extension [PostGIS](#). MobilityDB follows the [Moving Features](#) specification from the [Open Geospatial Consortium](#) (OGC).

Technically, MobilityDB is implemented as a PostgreSQL [external extension](#).

MobilityDB is developed by the Computer & Decision Engineering Department of the [Université Libre de Bruxelles](#) (ULB) under the direction of [Prof. Esteban Zimányi](#).

### Features

- Time types `Period`, `PeriodSet`, and `TimestampSet` which, in addition of the the `TimestampTz` type provided by PostgreSQL, are used to represent time spans.

# Thanks for listening !

Questions ?

