

Geographical Information Systems for Spatio-Temporal Analysis of Mobile Networks in Barcelona



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Objectives

- Demonstrate the **integration** of the **Catalan Government's first crowdsourcing Project – “Mobile Coverage (GenCat)”** in a context of **Big ‘Spatial’ Data**.
- Develop **Location Analytics** of mobile phone data (**point cloud**) in a **space-time context** considering **summarization techniques** and **hotspot detection** under a **cloud computing framework**.
- Develop **geovisualization** capabilities for the exploitation of **mobile(statistical)-based indicators** of the quality of mobile networks (hotspots of precision and signal level by 2G, 3G and 4G) **at different geographical granularity levels** in **Barcelona**.



Research questions

- (1) Can we **define**, **calculate** and **visualize** meaningful **spatial temporal indicators** using the **point clouds** of the Mobile Coverage (GenCat) **within** different **geographic granularity levels** in **Barcelona** (districts, neighborhoods and urban classes of Barcelona)?
- (2) **Exists** relevant **spatial** and **statistical differences** of this **crowdsourced dataset** **within neighborhoods** of **Barcelona**?



DATA

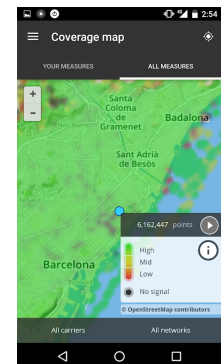
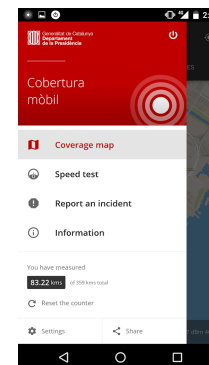
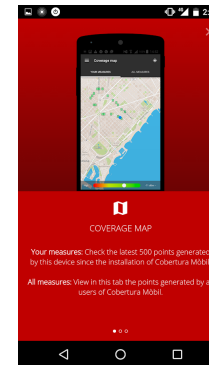
Mobile Coverage



gencat



Google Play

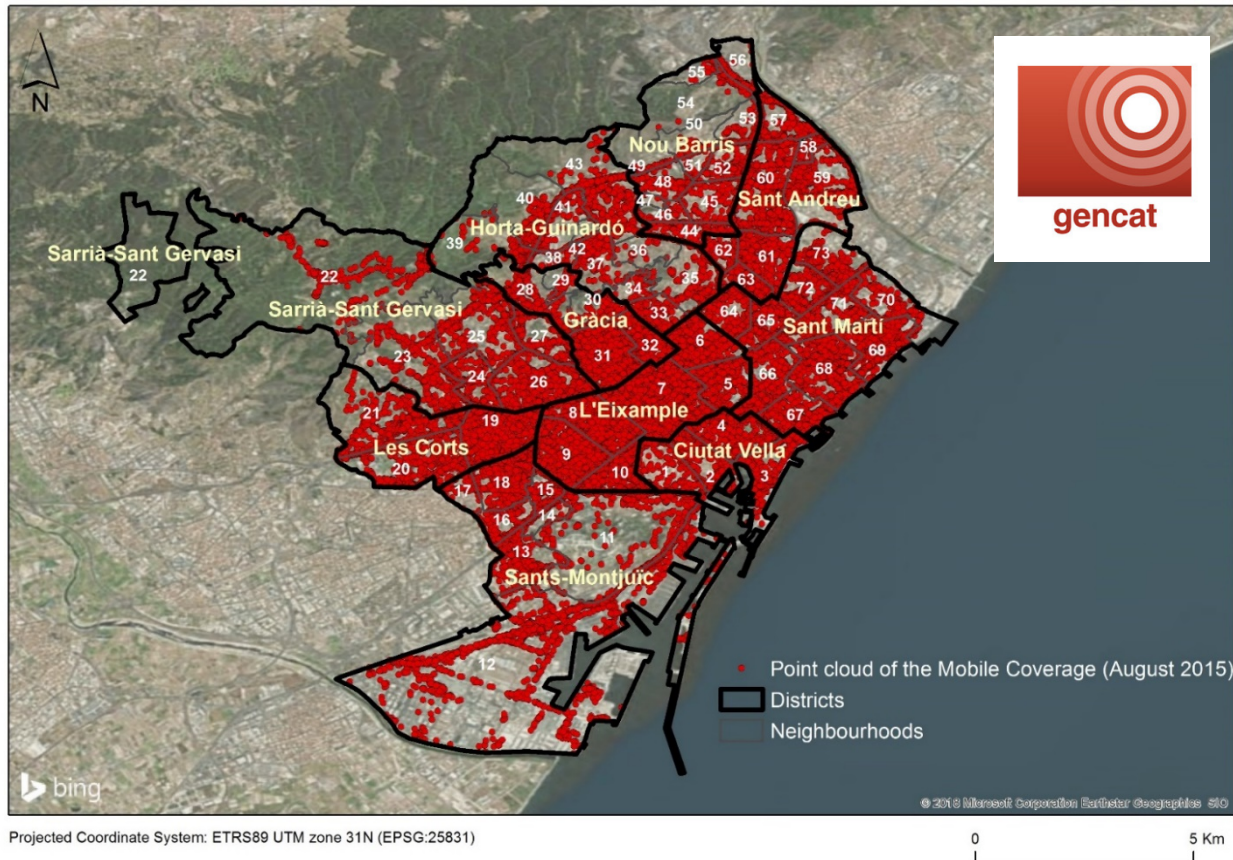


- **First Catalan Government's crowdsourcing project.**
- **Mobile Coverage intends to create a Heatmap to provide information on the state of mobile telephone network coverage in Catalonia.**
- **To identify the areas in Catalonia that need to improve their mobile coverage.**
- **Users can also check the quality of coverage in particular areas of Catalonia according to their chosen operator (Movistar, Vodafone, Orange or Yoigo) and filter the data according to the technology used (2G, 3G or 4G).**
- **These anonymous users, who have the app installed, can record data on their position and the level of coverage the operator in that zone is providing, which is sent to a server.**

<https://play.google.com/store/apps/details?id=cat.gencat.mobi.cobeturamobil&hl=en> US

DATA

Mobile Coverage in Barcelona



- Data collected by the Mobile Coverage application (2015-2017) (source *Dades obertes catalunya*).
- We analysed **47364** points for August 2015 distributed by the 10 districts and 73 neighborhoods of Barcelona.
- Relevant **variables** captured by the **Mobile GenCat app**:
 - *Date and time of measurement.*
 - *Network of the measured signal (Movistar, Vodafone, Orange or Yoigo).*
 - *Type of Network name (2G, 3G and 4G).*
 - *Average, Maximum and Minimum signal (in ASU).*
 - *Provider accuracy (Precision).*

DATA

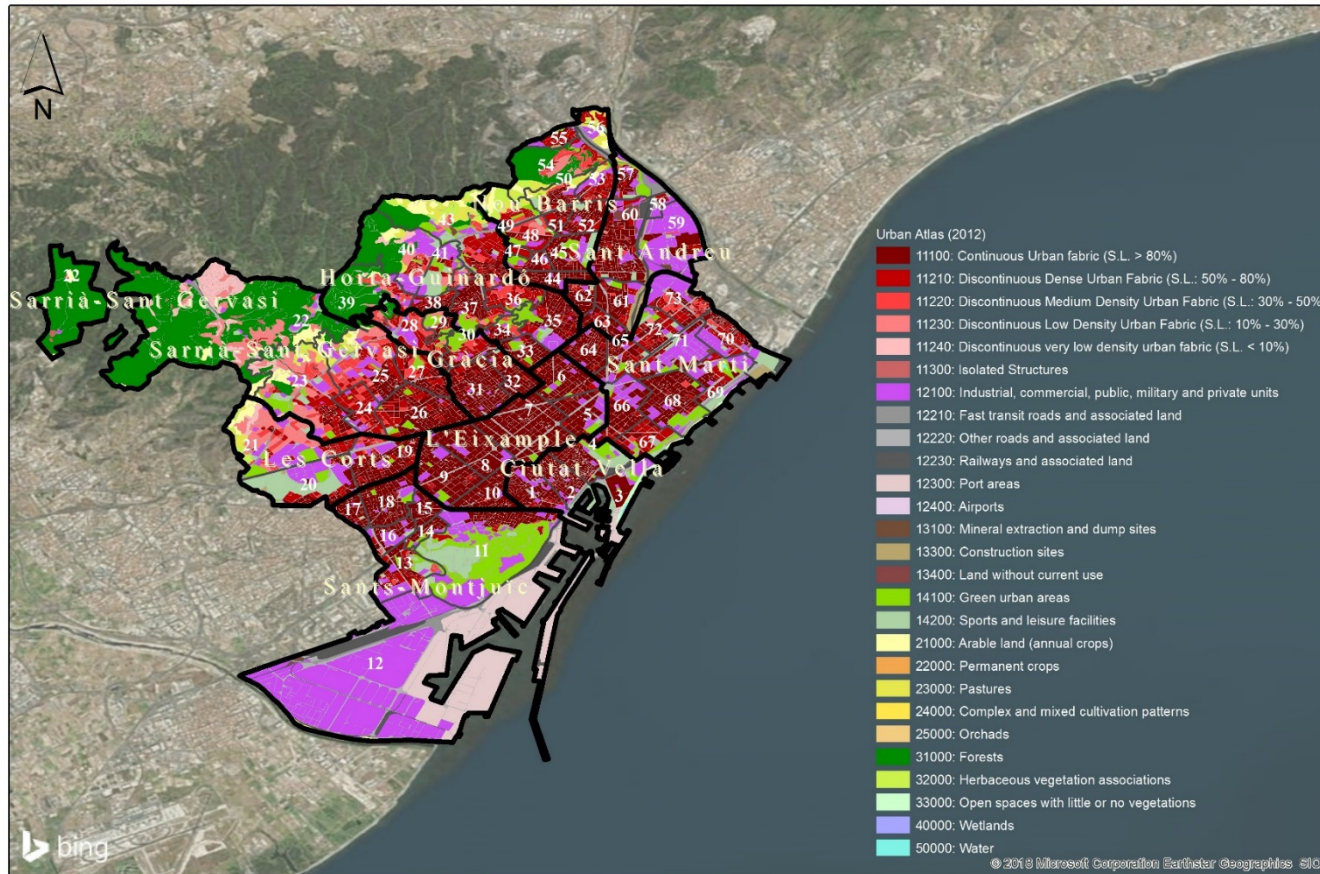
Urban Atlas

- The **Urban Atlas** provides pan-European comparable **Land Use and Land Cover (LULC)** data for **Functional Urban Areas (FUA)**, which consists of a city plus its commuting zone.
- Joint initiative of the **European Commission Directorate-General for Regional and Urban Policy** and the **Directorate-General for Enterprise and Industry** in the frame of the **EU Copernicus programme** with the support of the **European Space Agency (ESA)** and the **European Environment Agency (EEA)**.
- Regarding the **periodicity of the official information** to perform the analysis of the spatial temporal patterns of mobile coverage data (2015) within the urban classes (2012), **we assumed that between the period 2012-2015 the urban classes of the FUA of Barcelona are not as subject to significant transformations on LULC.**



DATA

Urban Atlas



Projected Coordinate System: ETRS89 UTM zone 31N (EPSG:25831)

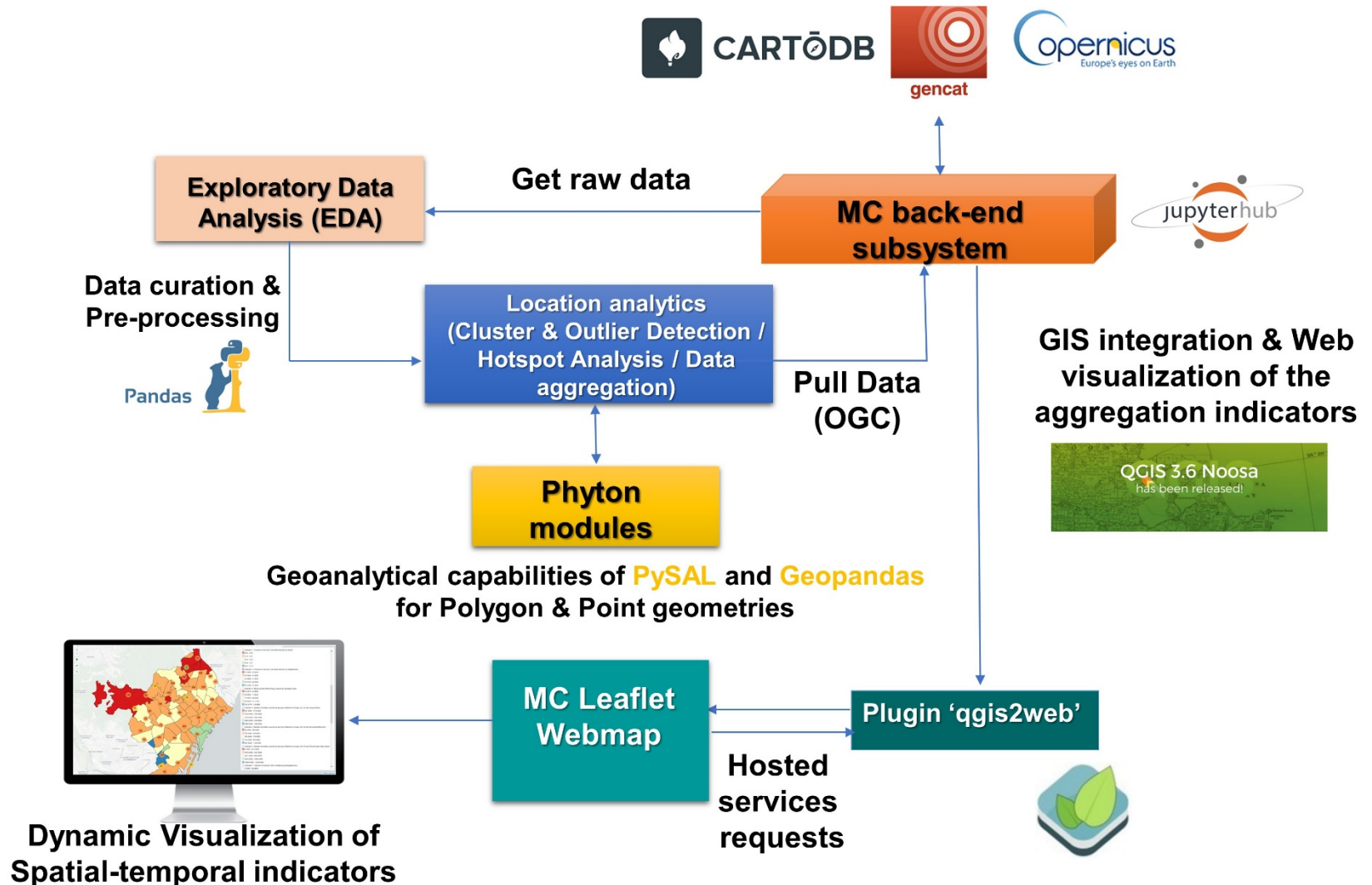
0 6 Km



- The data set “**Urban Atlas 2012**” for the FUA “**Barcelona City**” includes a nomenclature with:
 - 17 urban classes with MMU (Minimum Mapping Unit) 0.25 ha.
 - 10 Rural Classes with MMU 1ha.

SYSTEM ARCHITECTURE

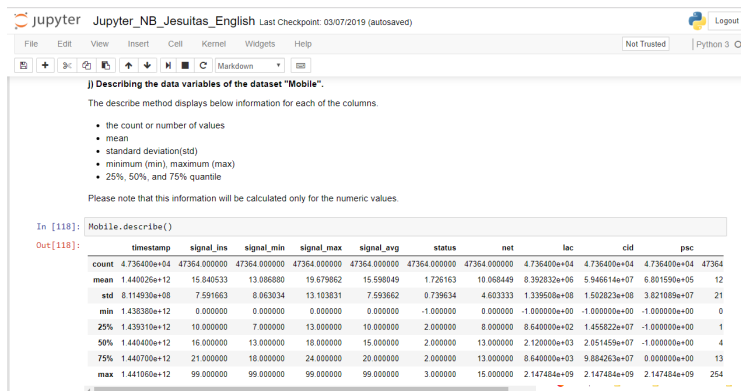
“Mobile Coverage (MC) Framework”



METHODS FOR CURATION AND PRE-PROCESSING

Exploratory Data Analysis (EDA) of Mobile Coverage data

- Exploring **statistical information** (Descriptive statistics, Correlation, etc) of the mobile data source for August 2015.



We can also use the corresponding method to access this information one at a time. For example, to get the mean method on that column.

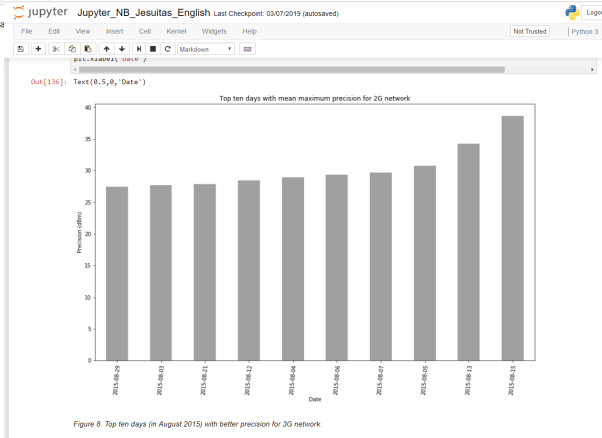
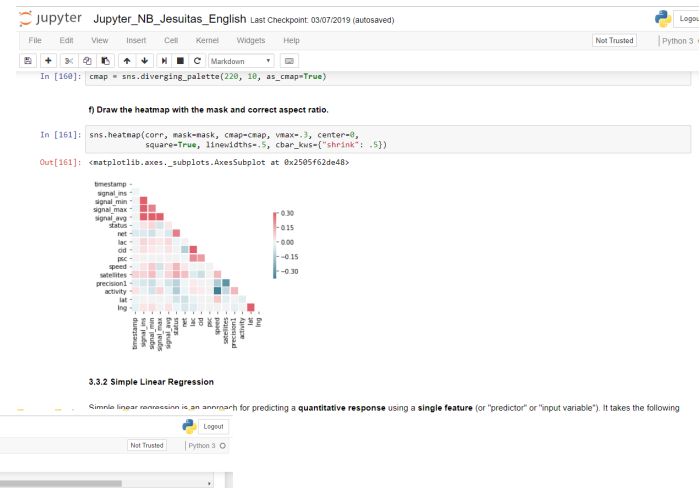
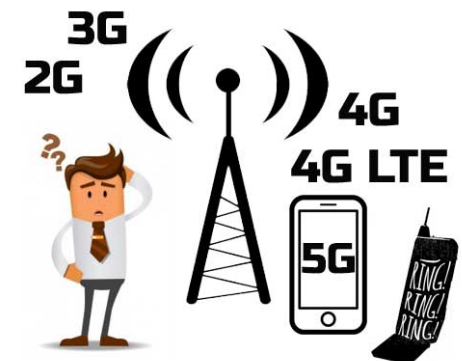


Figure 8. Top ten days (in August 2015) with better precision for 2G network.



3.3.2 Simple Linear Regression

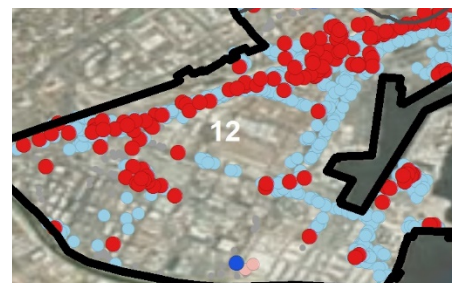
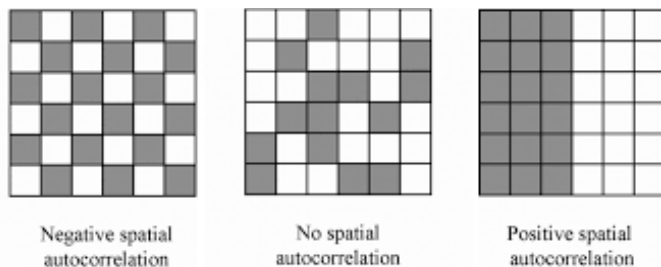
Simple linear regression is an approach for predicting a quantitative response using a single feature (or "predictor" or "input variable"). It takes the following



METHODS FOR LOCATION ANALYTICS

Cluster and Outlier Detection (Global Moran's I and Local Moran's I)

- The **global spatial autocorrelation** measures the clustering of values of a **variable** inside a geographical area, as the **existence of zones of higher or lower values**, such as the measurements of precision of mobile networks.
- The **null hypotheses** is that **values reveals a random distribution in space**.
 - **High-High (HH) Cluster** - Local spatial cluster of high values: high value features surrounded by other high value features in their neighborhood.
 - **Low-Low (LL) Cluster** - Local spatial cluster of low values: low value features surrounded by other low value features in their neighborhood.
 - **High-Low (HL) Outlier** - Local high spatial outlier: high value features surrounded by low value features in their neighborhood.
 - **Low-High (LH) Outlier** - Local low spatial outlier: low value features surrounded by high value features in their neighborhood.

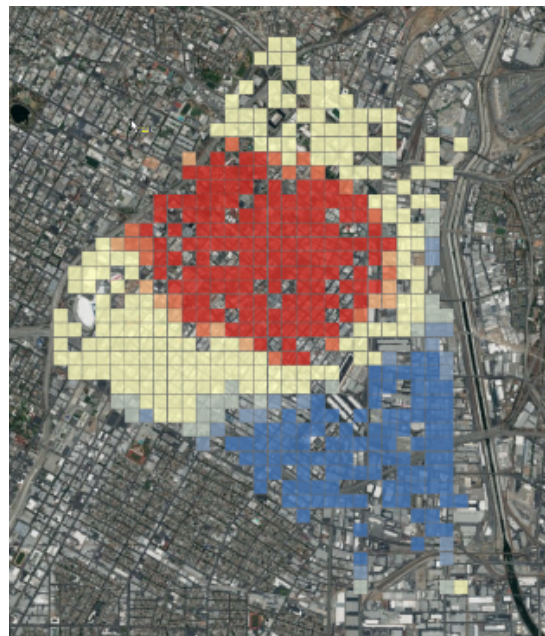


- Not Significant
- High-High Cluster (HH)
- Low-Low Cluster (LL)
- High-Low Outlier (HL)
- Low-High Outlier (LH)

METHODS FOR LOCATION ANALYTICS

Hot and Cold Spots (Local Getis-Ord's G^*)

- **Statistical significance** of the **clusters** was further **categorized** with the **values under the thresholds of 0.05** (statistically significant), **0.01** (highly statistically significant) and **0.001** (very highly statistically significant).
- In this sense, the **Hot Spot Analysis script** calculates the **Getis-Ord G^* statistic for each feature** in the dataset.
- **Statistically significant spatial clusters of high values** (**hot spots**) and **low values** (**cold spots**) were identified in the studied area.



- Cold Spot - 99% Confidence
- Cold Spot - 95% Confidence
- Cold Spot - 90% Confidence
- Not Significant
- Hot Spot - 90% Confidence
- Hot Spot - 95% Confidence
- Hot Spot - 99% Confidence

METHODS FOR LOCATION ANALYTICS

Mobile(statistical)-based indicators

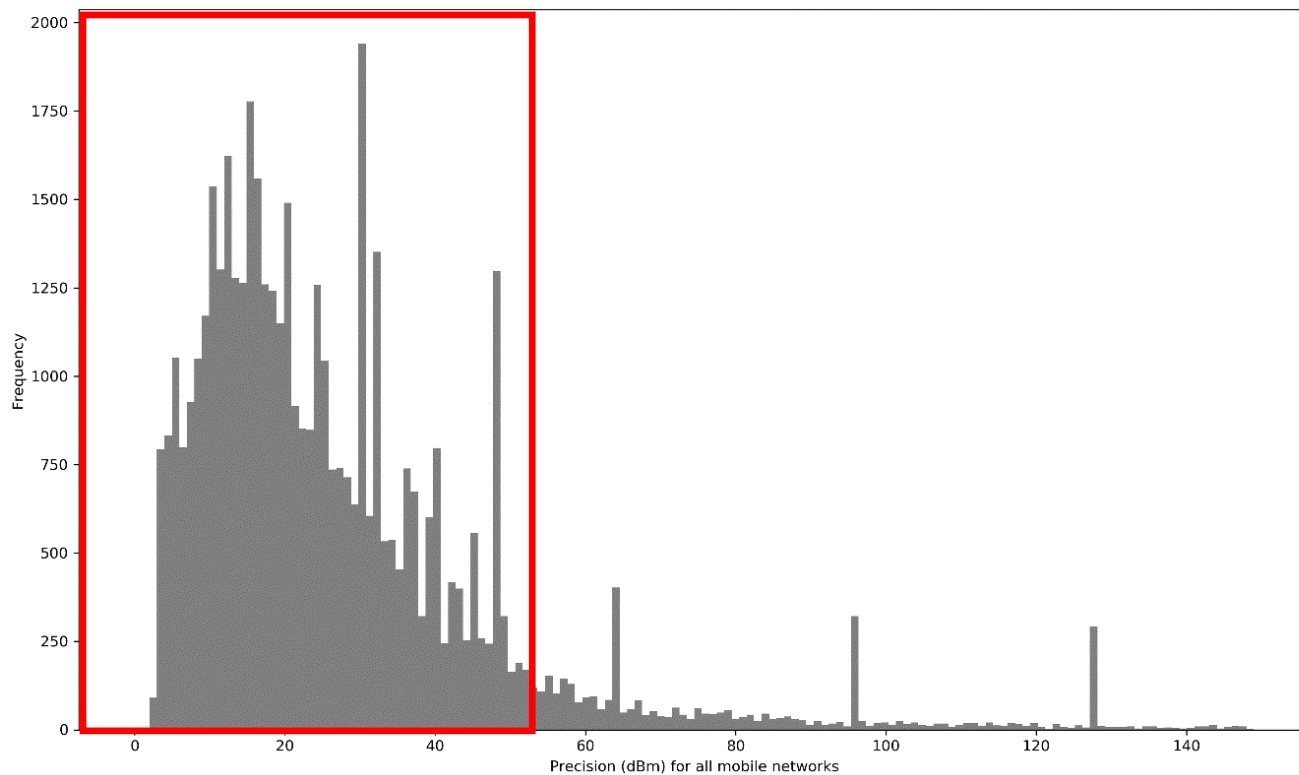
- **Thirteen aggregation indicators** of precision, signal, number of monthly occurrences per type of Network coverage (2G, 3G and 4G), number of Hot and Cold Spot based on the granularity levels.
- ✓ **Indicator 1** - *Precision of the best of all mobile networks by district.*
- ✓ **Indicator 2** - *Precision of the best of all mobile networks by Neighborhood.*
- ✓ **Indicator 3** - *Measurements of the Orange network by granularity levels.*
- ✓ **Indicator 4** - *Number of monthly occurrences per type of Network coverage (2G, 3G and 4G) per district.*
- ✓ **Indicator 5** - *Number of monthly occurrences per type of Network coverage (2G, 3G and 4G) per Neighborhood.*
- ✓ **Indicator 6** - *Number of monthly occurrences per type of Network coverage (2G, 3G and 4G) per Urban Atlas classes.*
- ✓ **Indicators 7, 8, 9** - *Number of Cold Spot (99%, 95%, 90% Confidence) per Neighborhood.*
- ✓ **Indicator 10** – *Number of Not Significant clusters per Neighborhood.*
- ✓ **Indicators 11, 12 and 13** - *Number of Hot Spot (90%, 95%, 99% Confidence) per Neighborhood.*



RESULTS

Exploratory Data Analysis (EDA) of Mobile Coverage data

Precision for all mobile network

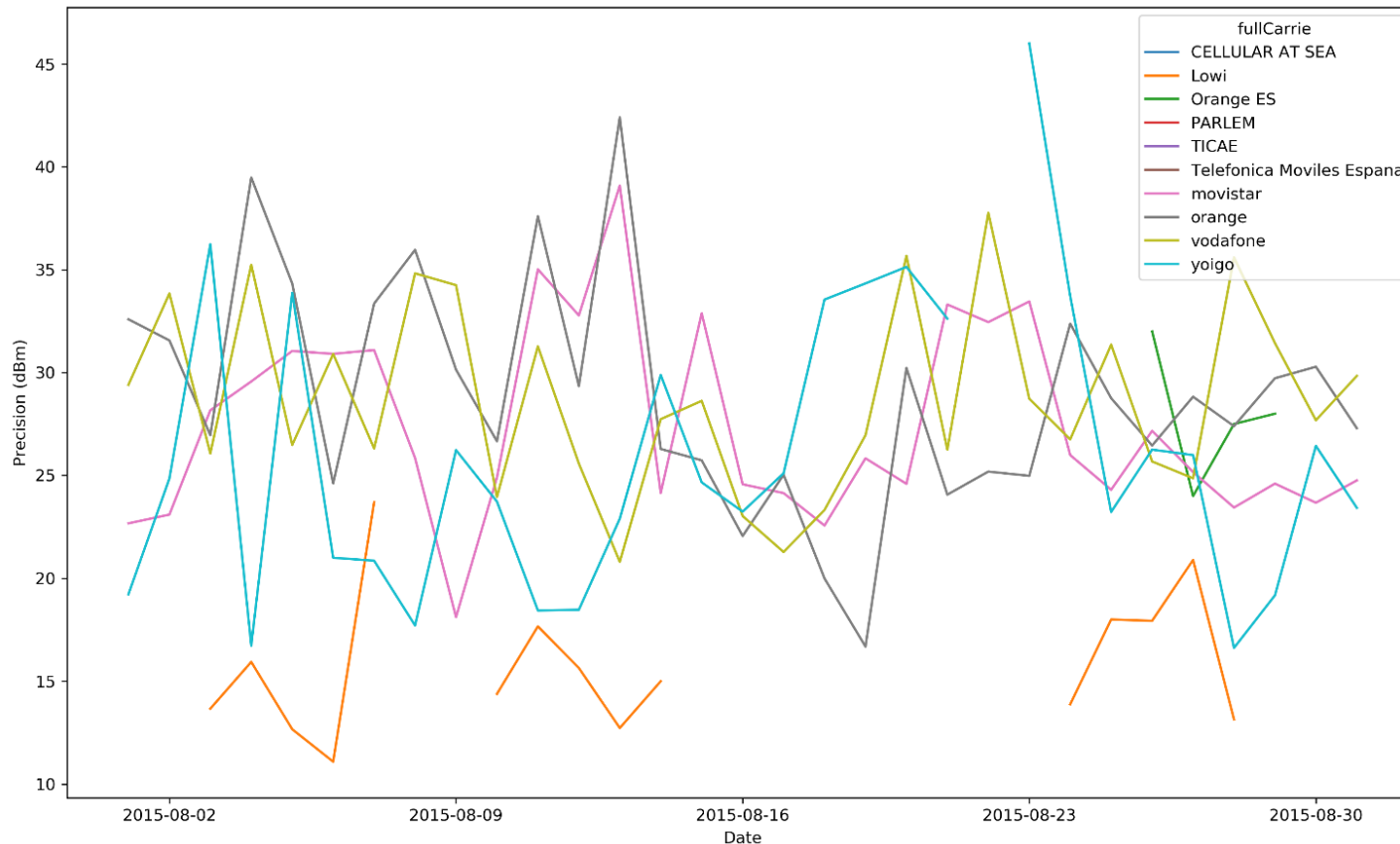


- Precision values vary from **0 to 149 dBm**, where the majority of the values are concentrated in the range between **0 and 50**.

RESULTS

Exploratory Data Analysis (EDA) of Mobile Coverage data

Precision of mobile network operators

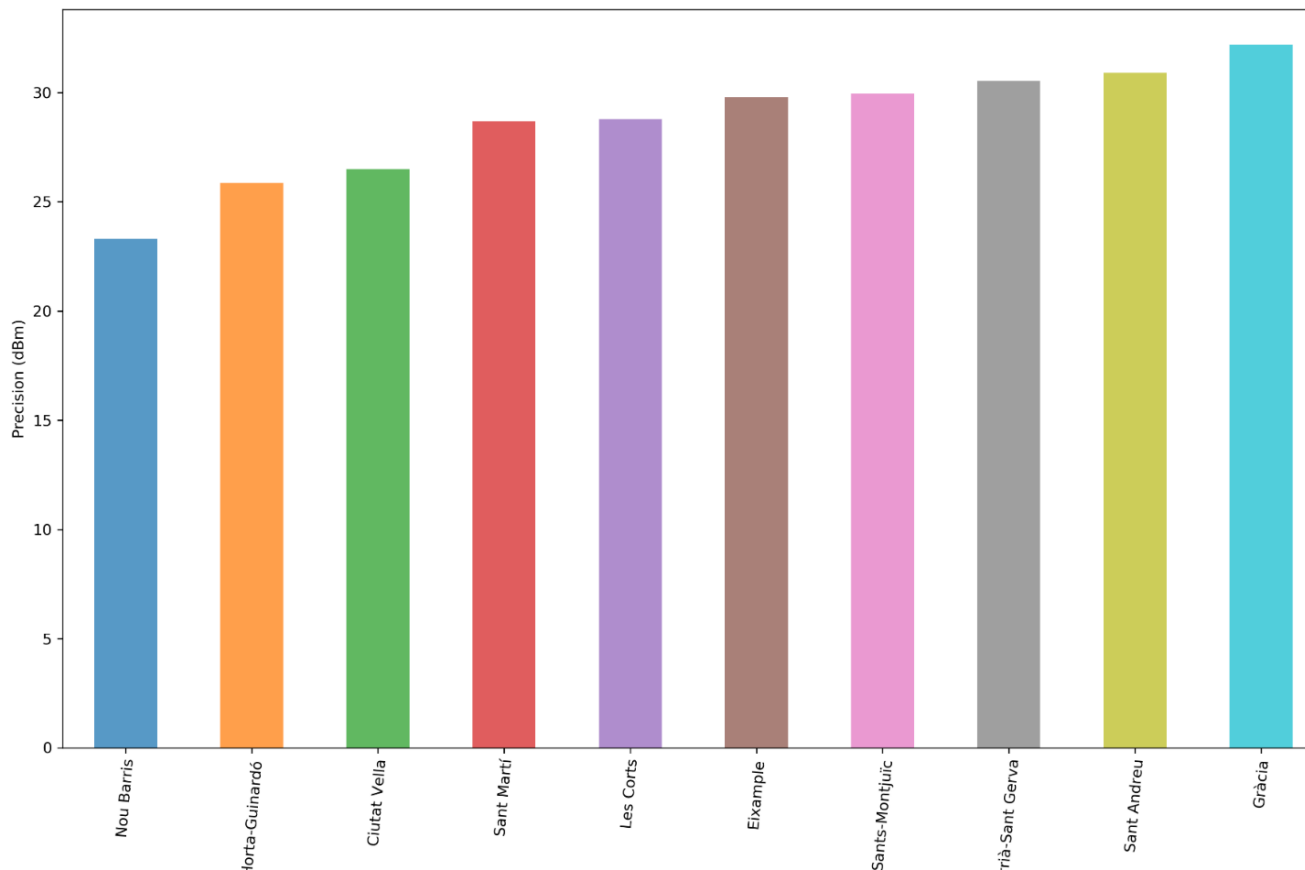


- Higher values for Orange, Movistar and Vodafone.
- Yoigo presents an irregular pattern throughout the month.
- Orange and Movistar reaches peak levels on 13 August.
- Vodafone on 22 August.

RESULTS

Exploratory Data Analysis (EDA) of Mobile Coverage data

Precision (dBm) of Orange network by district

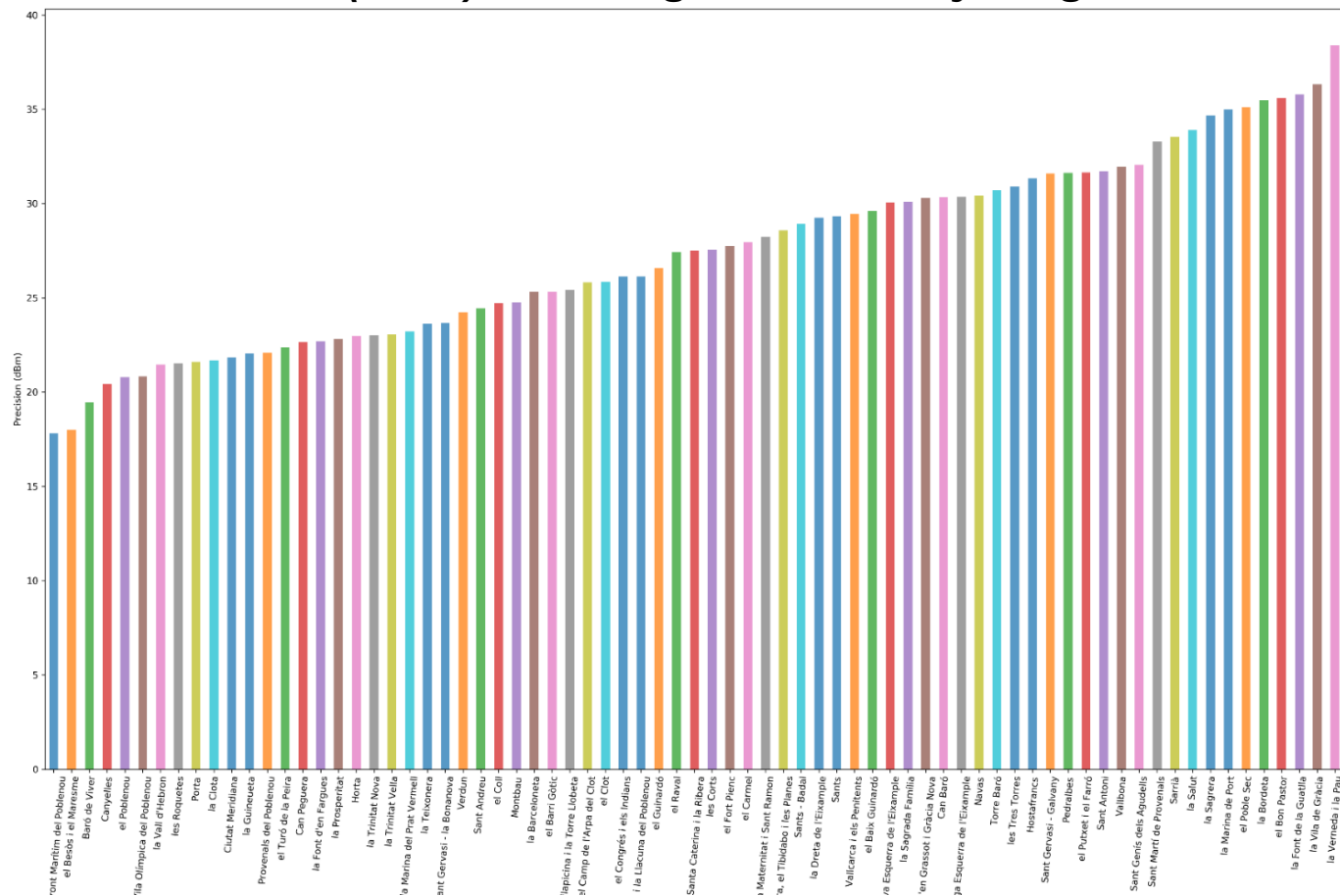


- **Higher values** of precision for:
 - **Gràcia** (32.2).
 - **Sant Andreu** (30.9).
 - **Sarrià-Sant Gervasi** (30.5).
- **Lower values** of precision for:
 - **Nou Barris** (23.3).
 - **Horta-Guinardó** (25.9).
 - **Ciutat Vella** (26.5).

RESULTS

Exploratory Data Analysis (EDA) of Mobile Coverage data

Precision (dBm) of Orange network by neighborhoods

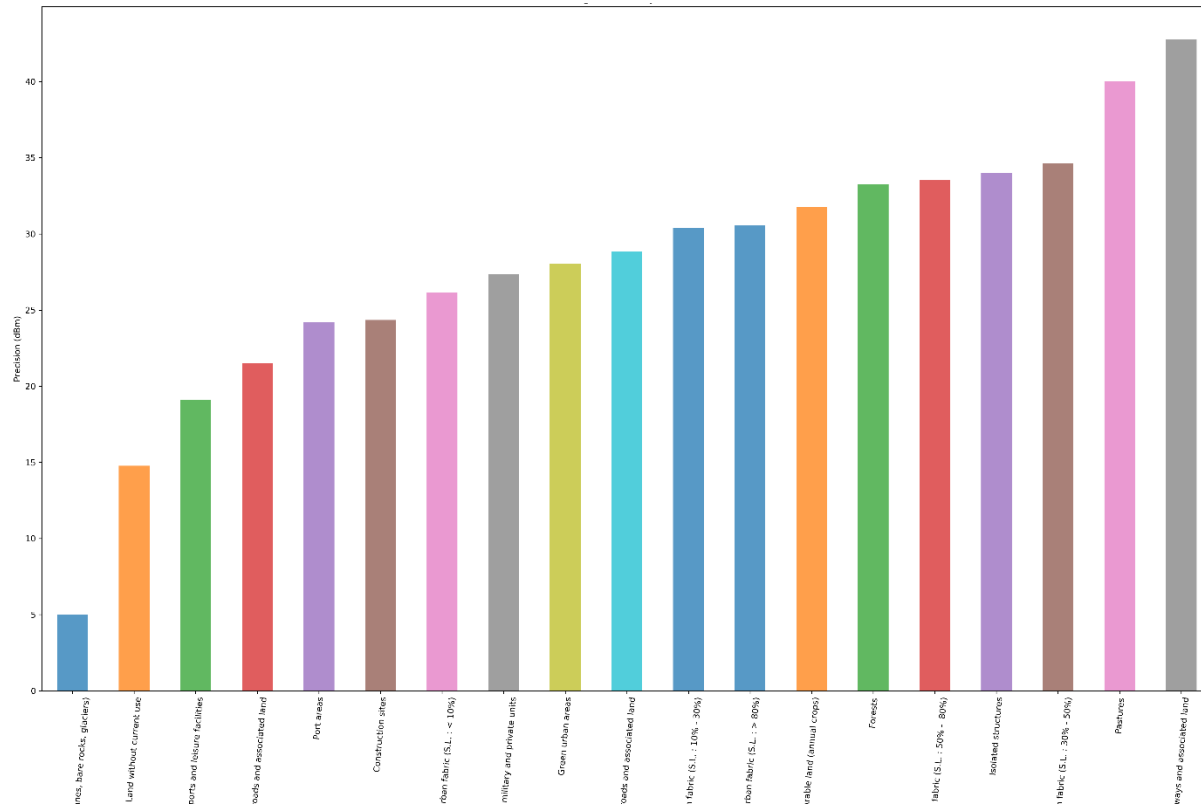


- Higher values of precision for **la Verneda i la Pau** (38.3) and **la Vila de Gràcia** (36.3).
- Lower values of precision for **Diagonal Mar i el Front Marítim del Poblenou** (17.8).

RESULTS

Exploratory Data Analysis (EDA) of Mobile Coverage data

Precision (dBm) of Orange network by Urban Atlas classes

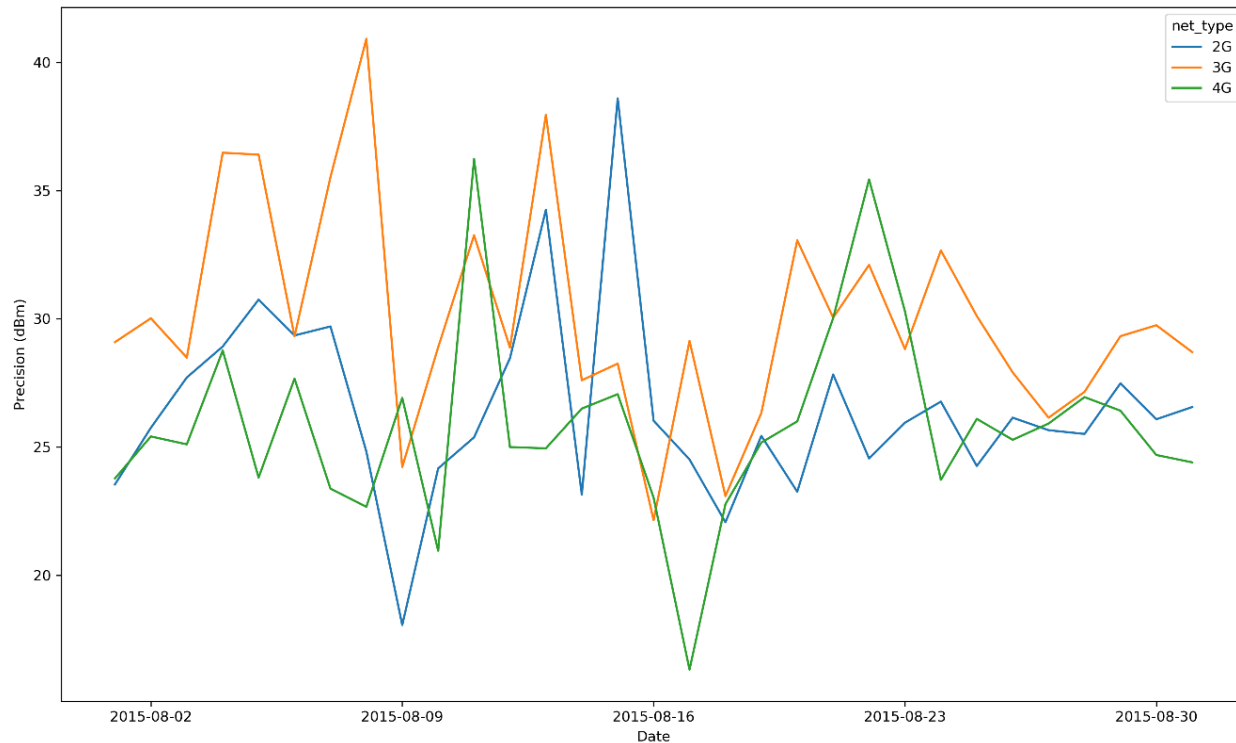


- Higher values of precision for **Railways and associated land** (42.8), **Pastures** (40) and **Discontinuous medium density urban fabric (S.L. : 30% - 50%)** (34.6).
- Lower values of precision for **Open spaces with little or no vegetation** (beaches, dunes, bare rocks, glaciers) (5).

RESULTS

Exploratory Data Analysis (EDA) of Mobile Coverage data

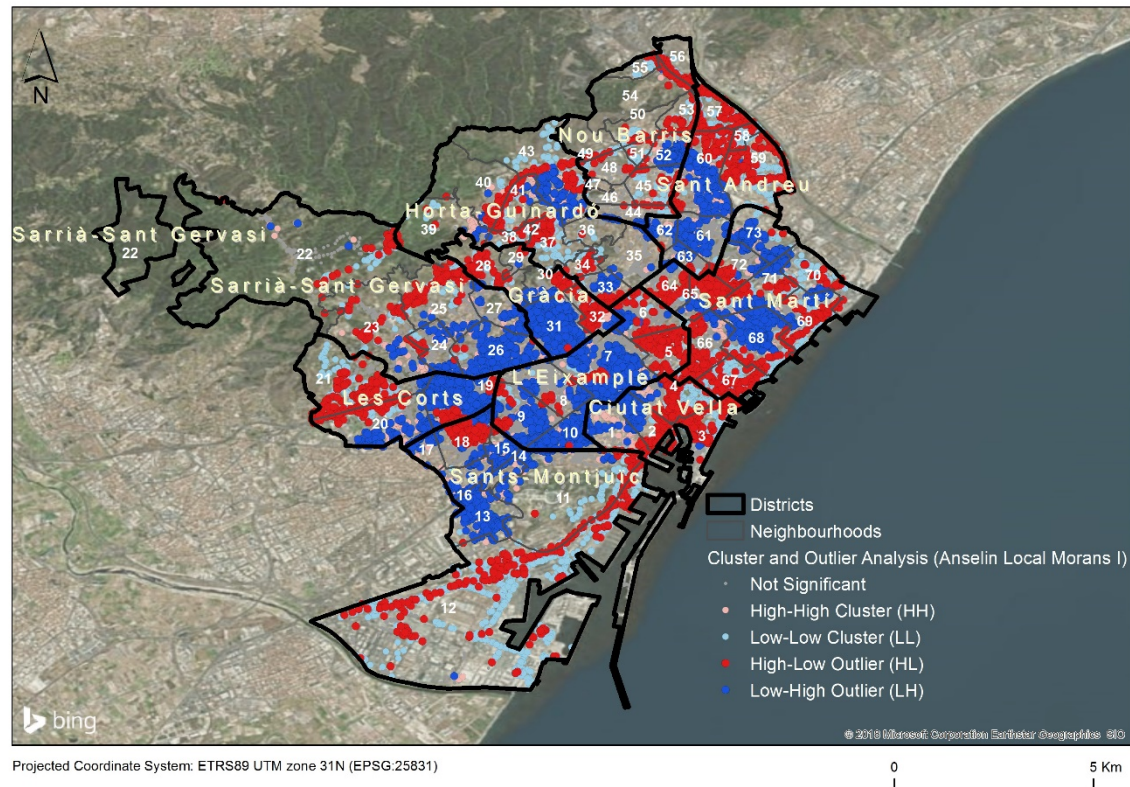
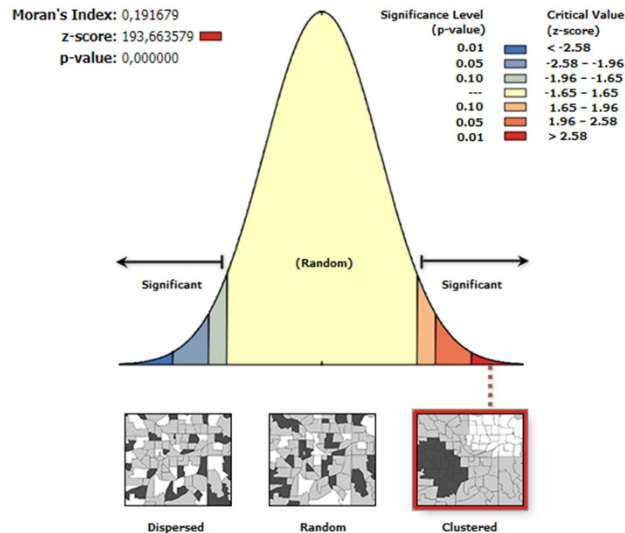
Precision (dBm) of 2G, 3G and 4G network type during August 2015



- Presence of **higher and more constant values** for the **3G network** during the month.
- The **2G** and **4G** exhibits a **more irregular pattern** with a relevant decrease of precision of 2G network at August 9 and a slightly increase of the precision of 2G at the middle of August.
- Evident **decrease** in the **4G** in 16 August and also an **increase** of this network type at 23 August.

RESULTS

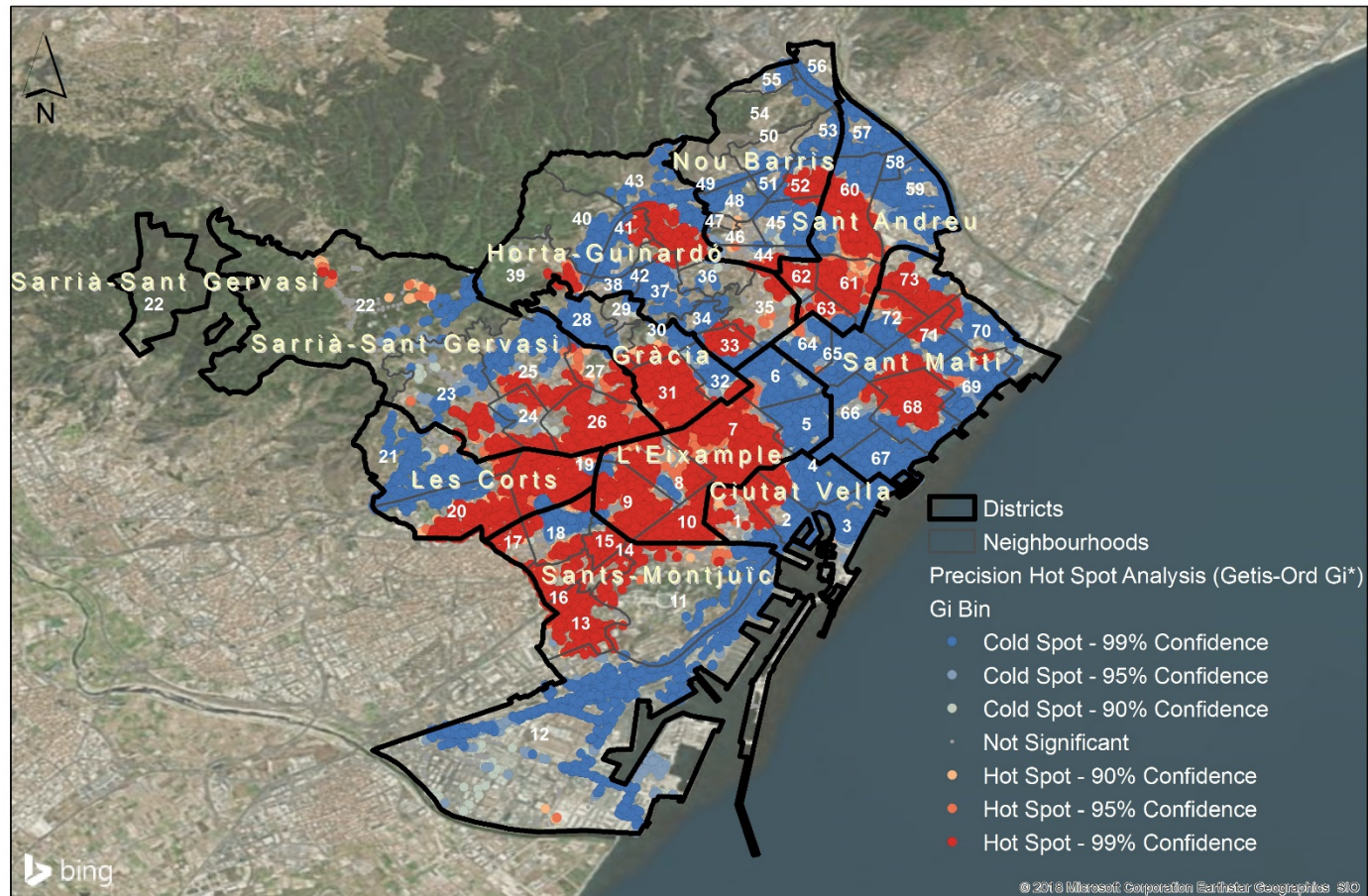
Cluster and Outlier Detection (Global Moran's I and Local Moran's I)



- Concerning the **Spatial Autocorrelation analysis** based on the variable “Precision”, we obtained a **Global Moran's I Index of 0.19** which indicates a **distribution of clustered values** in space.
- High-High Cluster (7943), High-Low Outlier (3077), Low-Low Cluster (12092) and Low-High Outlier (5948).

RESULTS

Hot and Cold Spots (Local Getis-Ord's G^*)

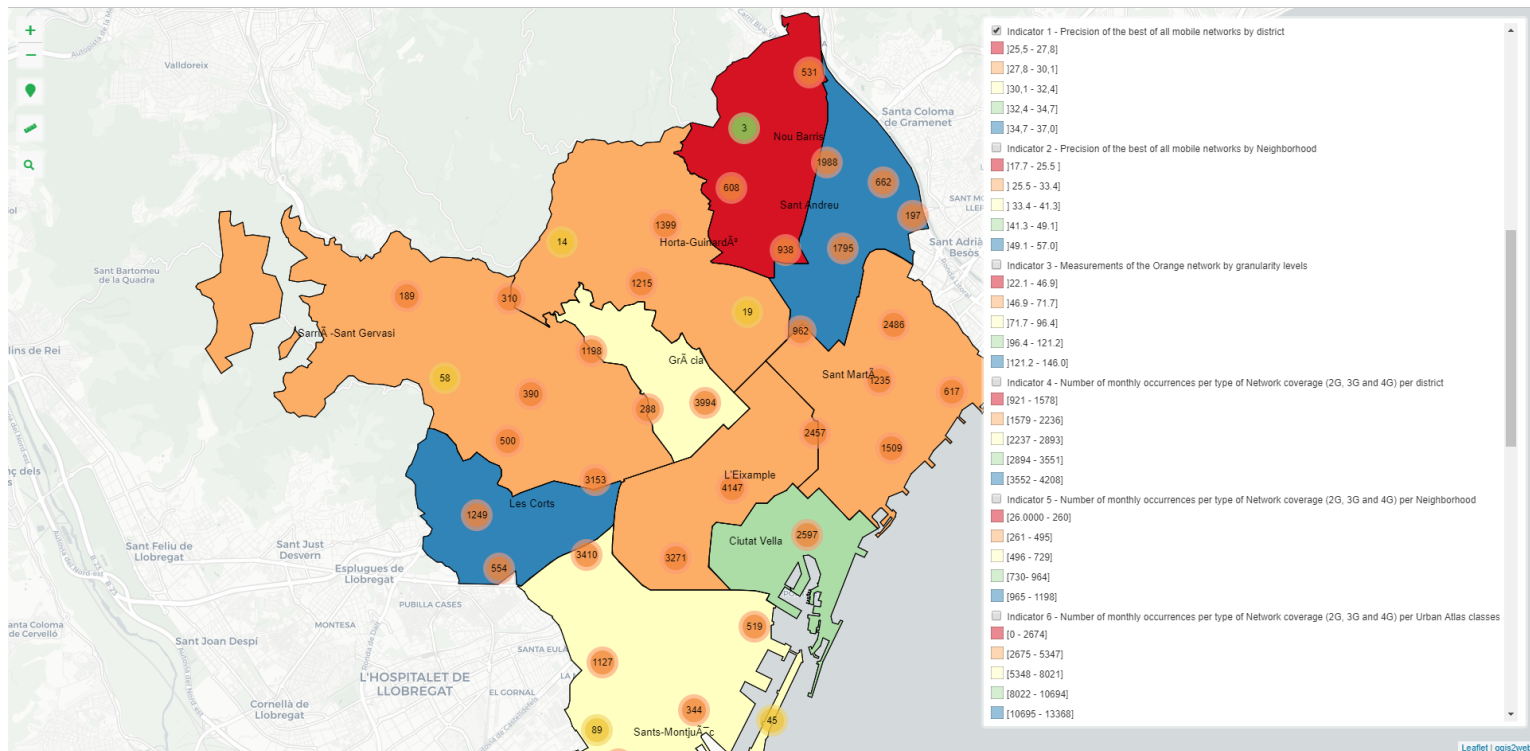


- **Prevalence of Cold Spot** (low-low cluster) and **Hot Spot** (high-high cluster) at **99% Confidence**. Without the consideration of spatial outliers (HL or LH).

RESULTS

Mobile(statistical)-based indicators

Precision of the best of all mobile networks by district

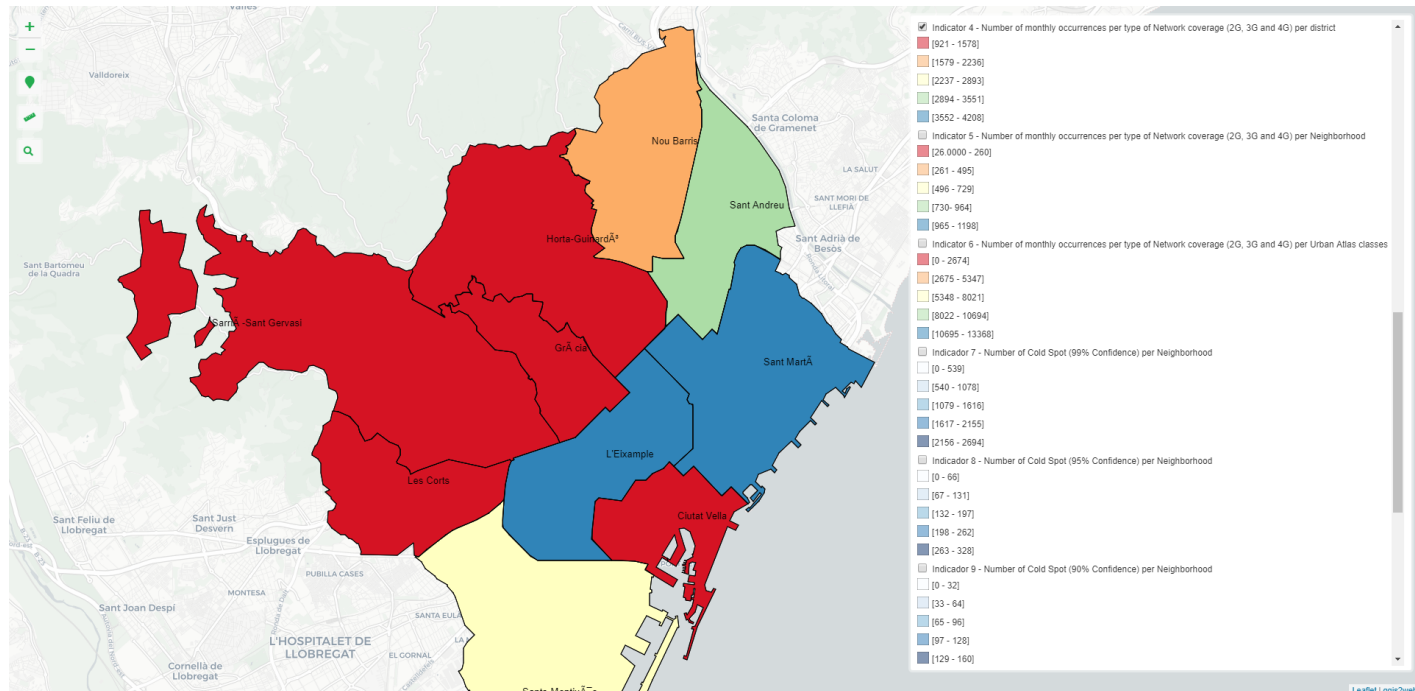


Sant Andreu the 'Ticæ' network presents the **highest value (37 dBm)**; 'Parlem' network in **Les Corts (35 dBm)**; 'Lowi' in **Ciutat Vella (34 dBm)** and **Sant Martí (28 dBm)**; 'Vodafone' in **Sants-Montjuïc (32 dBm)** and **Horta-Guinardó (29 dBm)**; 'Orange' in the districts of **Gràcia (32 dBm)**, **Sarrià-Sant Gervasi** and **L'Eixample** (both with 30 dBm); and finally 'Movistar' in **Nou Barris** with a precision value of 32 dBm.

RESULTS

Mobile(statistical)-based indicators

Number of monthly occurrences per type of Network coverage (2G, 3G and 4G) per district

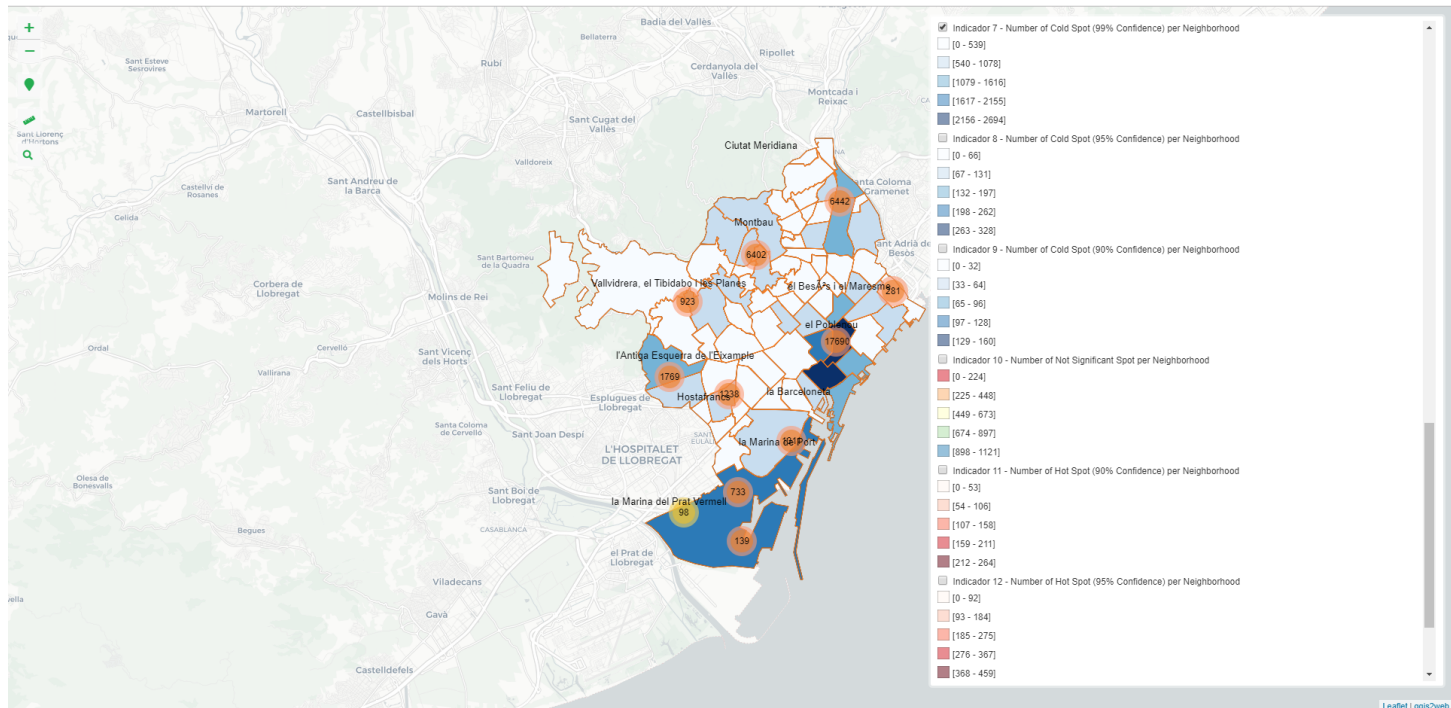


Sant Martí presents the **highest values** for **2G** (4120), **3G** (7182) and **4G** (7235); district of **Eixample** with **4280** occurrences for **2G** type (higher than in Sant Martí), **6783** occurrences for **3G** and **6407** occurrences for **4G** (both lower than in Sant Martí). On the other hand, the **minimum values** for **2G** type occurs in the district of **Horta-Guinardó** (with 921 presences), for **3G** type in the district of **Nou Barris** with 2494 and for **4G** type in **Sant Andreu** with 2670 occurrences.

RESULTS

Mobile(statistical)-based indicators

Number of Cold Spot (99% Confidence) per Neighborhood



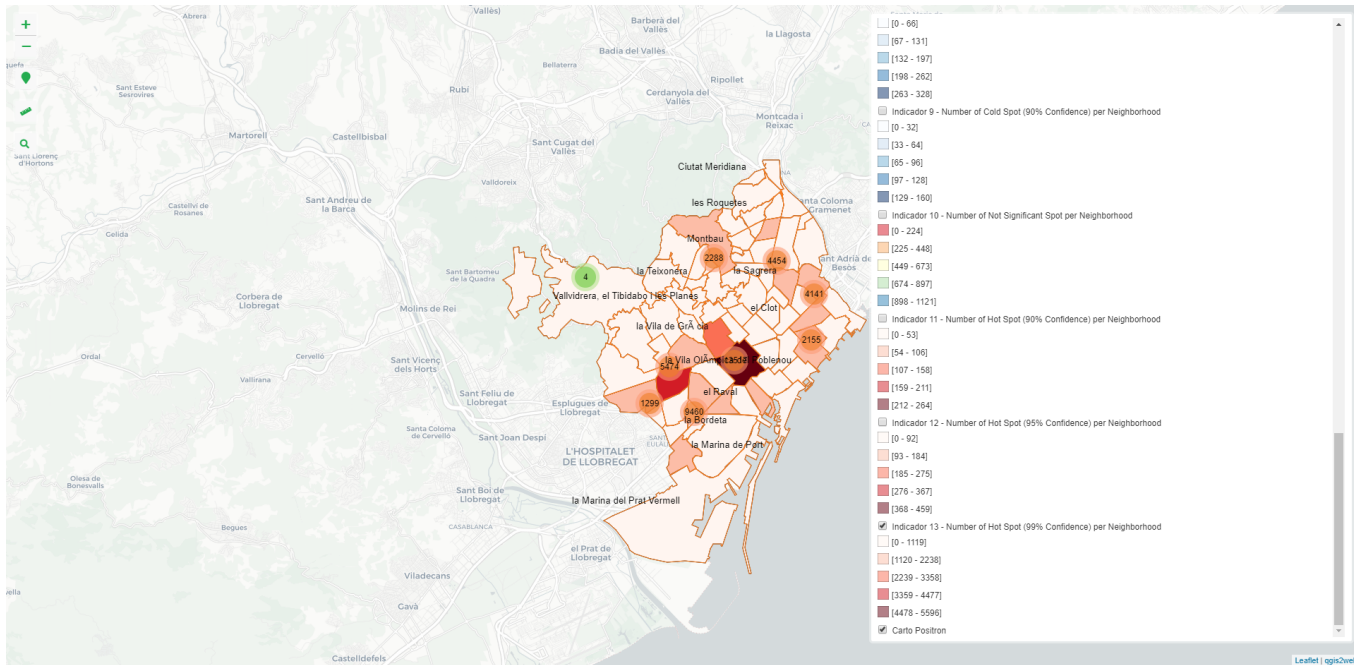
Neighborhoods of **El Parc i la Llacuna del Poblenou** with **2694**, **Sant Pere, Santa Caterina i la Ribera** with **2514**, **Fort Pienc** with **1789**, **La Marina del Prat Vermell** (**1646**) and **El Clot** with **1370** are the **most representative of Cold Spot**.

On the other hand, the neighborhoods of **Sant Antoni, La Marina de Port, La Font de la Guatlla, La Bordeta, Sants-Badal, Sant Gervasi – Galvany, El Congrés i els Indians** do not have any Cold Spot occurrence.

RESULTS

Mobile(statistical)-based indicators

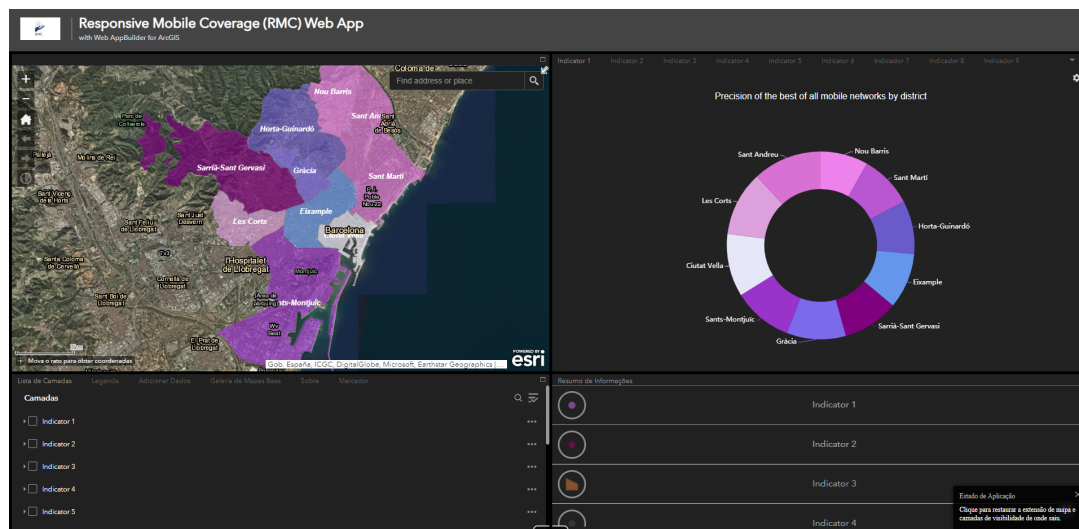
Number of Hot Spot (99% Confidence) per Neighborhood



Dreta de l'Eixample (5596), Les Corts (4217), Vila de Gràcia (3136), Horta (1982) and La Verneda i la Pau (1935) have a **higher number of Hot Spot occurrences**. On the other hand, **La Barceloneta, El Coll, La Teixonera, Montbau, El Turó de la Peira, Can Peguera, La Guineueta, Canyelles, Roquetes, Verdum, La Trinitat Nova, Torre Baró, Ciutat Meridiana, Vallbona, Trinitat Vella, Baró de Viver, El Camp de l'Arpa del Clot, El Clot and La Vila Olímpica del Poblenou do not have any Hot Spot occurrence.**

CONCLUSIONS

- The **developed methods** have potential for the **definition and analysis** of the **distribution of aggregation indicators** based on **Cloud points** in **cities**, **monitoring** the **precision** of **mobile networks** in **different administrative** and **urban** contexts.
- The **proposed solution** presents capabilities to **integrate additional information** from the Catalanian Big Data landscape, and therefore, **improve** the **access to Open data** for public sector, private companies, citizens and scientists.
- The **framework** based on **Cloud technologies** allows the **Exploratory Data Analysis (EDA)** of a **large number of point data** of mobile networks using **Jupyter (Python)**, and a **web visualization** of the **aggregation indicators** using the **QGIS Python Plugin “qgis2web”**.
- This study reveals a **lack of QGIS plugins** for the development of **responsive web mapping solutions** as is the case of interactive dashboard options provided by the ArcGIS OS frameworks (ArcGIS Online & Web AppBuilder for ArcGIS).



QUESTIONS

Geographical Information Systems for Spatio-Temporal Analysis of Mobile Networks in Barcelona



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