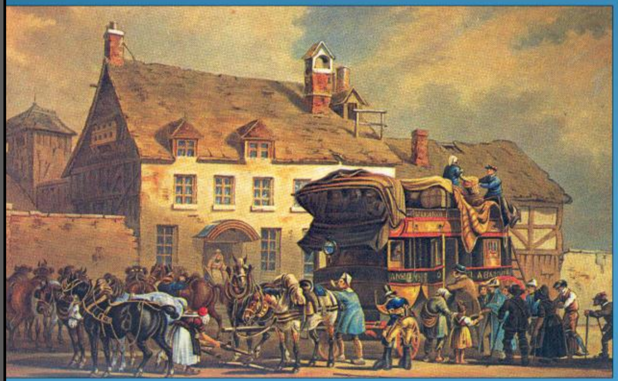
Analysing the co-evolution of postal roads and cities in France (16^{th}-19^{th} centuries)



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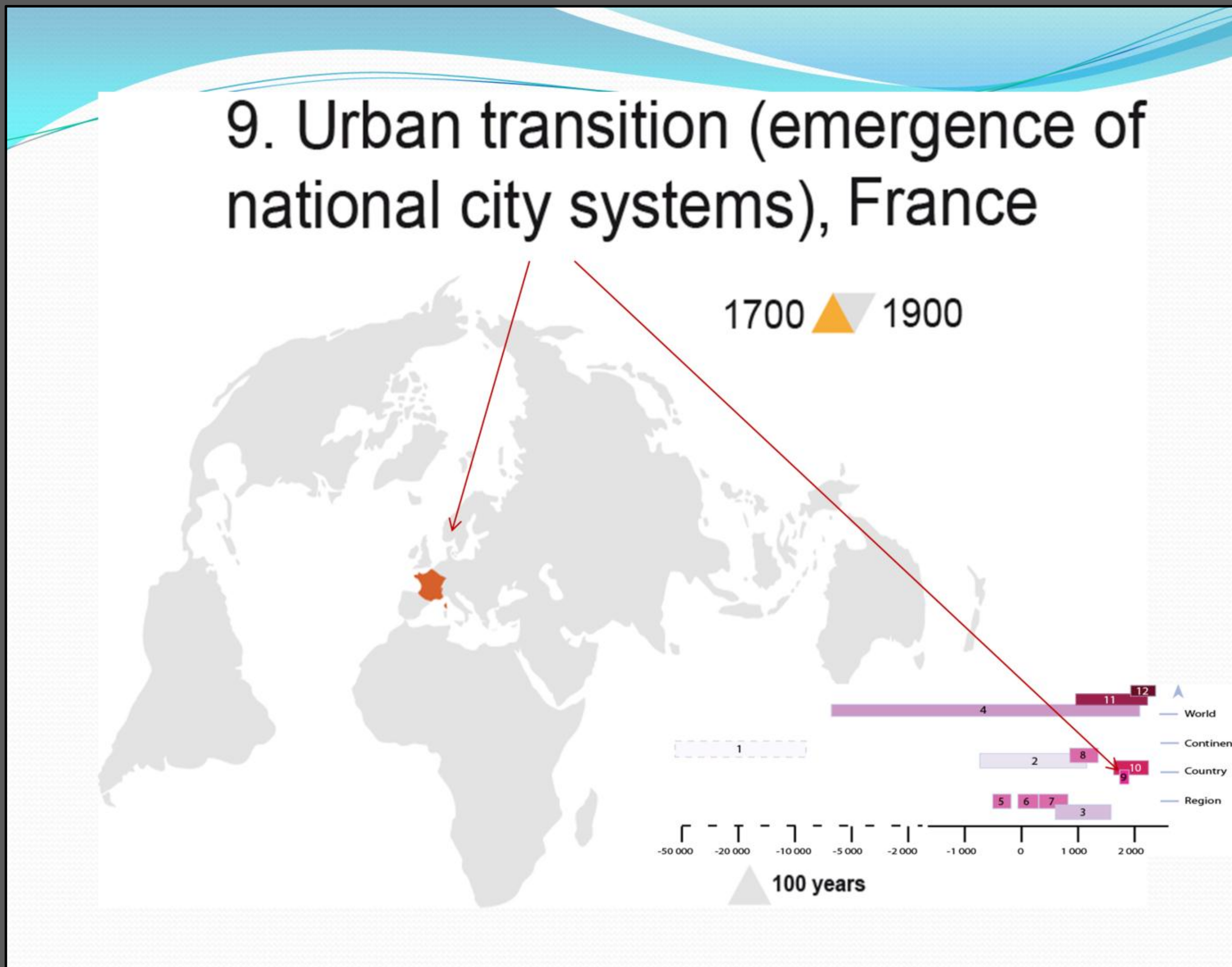
WSU Department of Anthropology and College of Arts and Science , Pullman November 13st 2014



Transition number 9 of the Transmondyn project is called Urban Transition and corresponds to the transformation of urban settlements in France in the 18th and 19th centuries. A first change consists in a major urban growth and increase in the level of hierarchical contrasts in the distribution of city sizes. A second change is the emergence of a national urban system, with strong inter-dependances between cities at the scale of the whole country.

Introduction

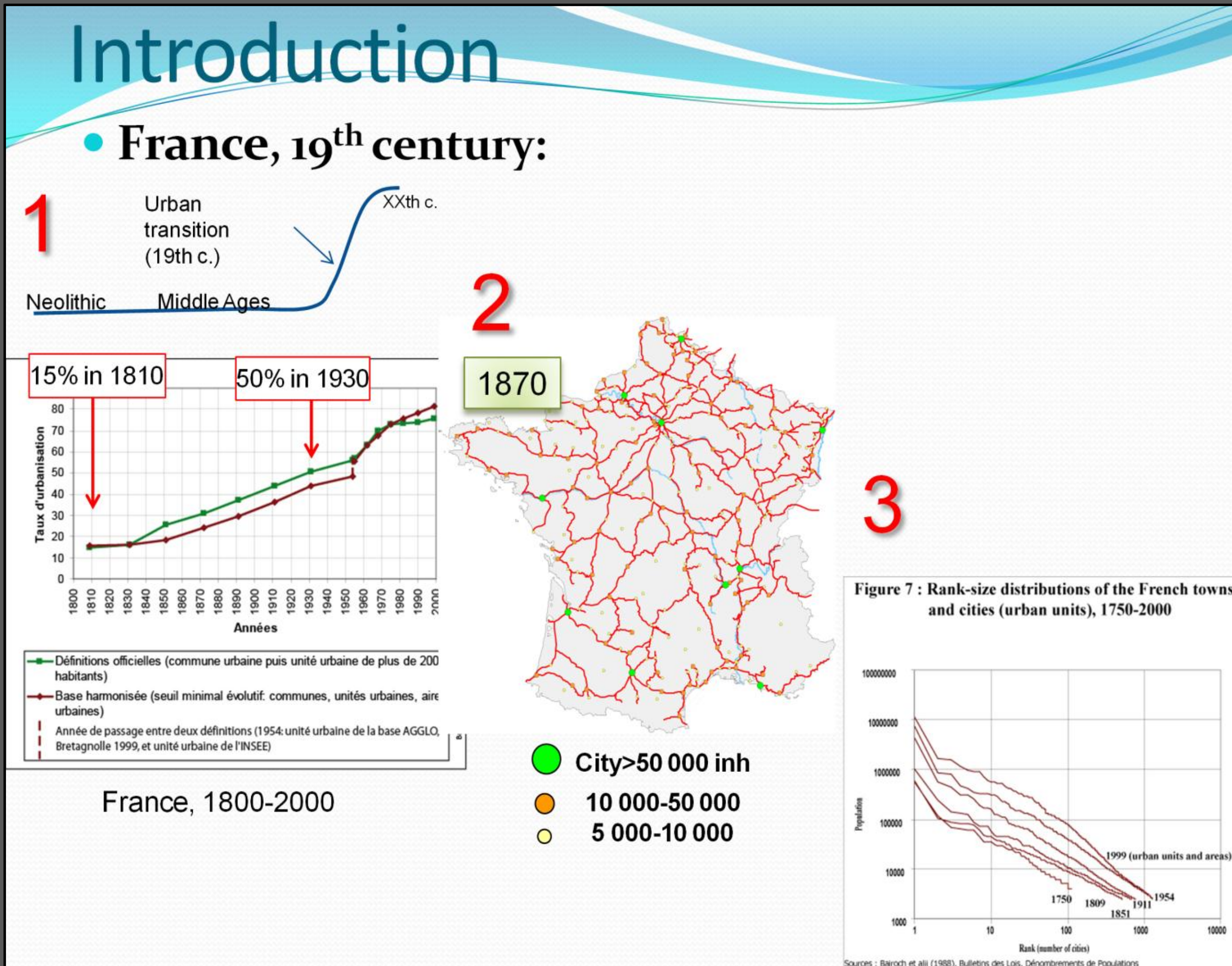
- How to define **national city systems**?
  - Berry Brian (1966), “ Cities as systems within systems of cities” :

> “… cities may be considered as systems-entities comprising interacting, inter-dependant parts. They may be studied at a variety of levels, structural, functional and dynamic, and they may be partitioned into a variety of sub-systems”

Inter-dependance: strong links between cities → role of information networks (Allan Pred, Brian Robson), for instance the postal roads

Scale: here national (France) → Which spatial integration processes transformed a set of cities into a system of cities at this scale?

Among the different properties of city systems stressed by geographers, inter-dependances based on communication networks (especially information) play a central role. Our main hypothesis is that the establishment of these inter-dependances at the national scale relies on the reinforcement of the medium scale (medium-sized cities, regional level), that is necessary for integrating in one system all the sets of cities spread out across France.

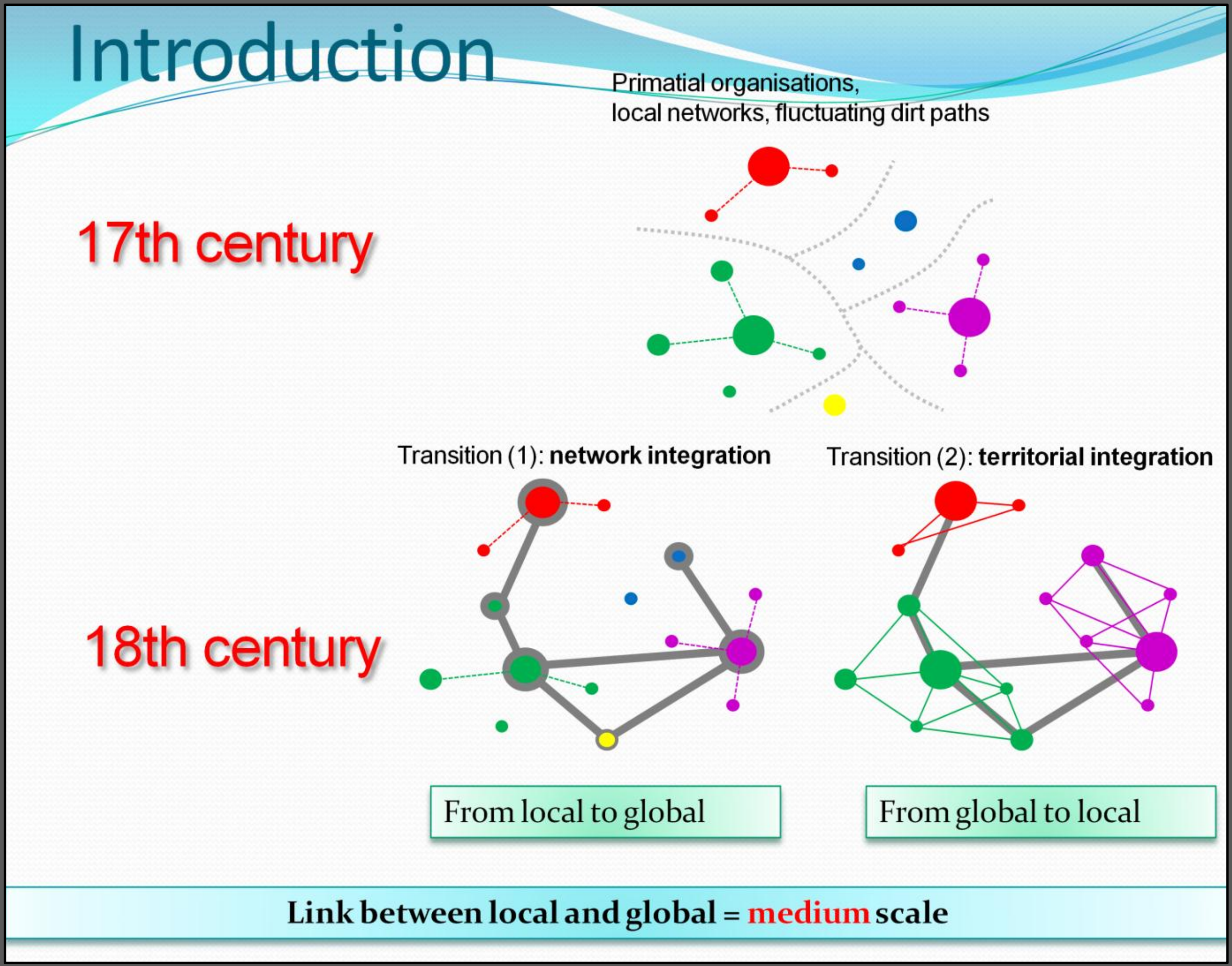


In France, a national city-system has been well established by historians and geographers in the 19th century according to three different reasons. First, there is a major urban growth that corresponds to the « urban transition » quoted by Zelinski (1979): due to rural exodus, population becomes mainly urban in a relatively short period. Only 15% of the French population lived in cities in 1810, and 50% in 1930. Secondly, there are strong links between cities through the new railroads, as shown for instance on the 1870 map. Third, the distribution of city sizes (with the ranks by decreasing order in x-axis and the population in y-axis) becomes more and more contrasted through time, meaning that the largest cities grow faster than the average. It is a process of urban concentration.

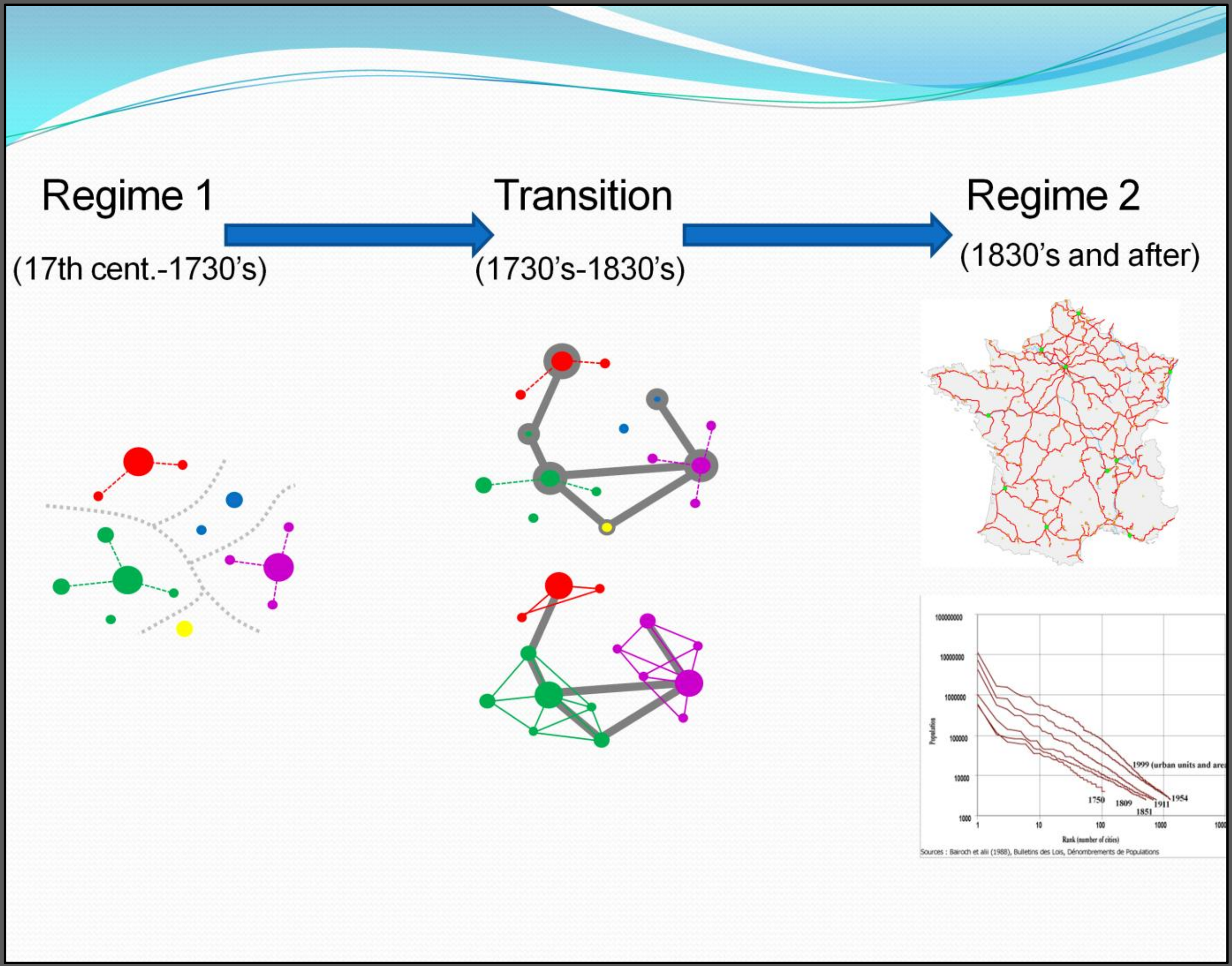
Introduction

- **France, 18th century?**
- Urbanization level increased from 15% to 20% between 1740 and 1780's (before the 1789 Revolution and Imperial wars)
- … in correlation with two major changes
  - New road network and new speed (postal coaches, diligences) between 1750's and 1780's
  - Major impulse in ports activity, textile/manufacturing coming from the maritime trade (colonial trade)

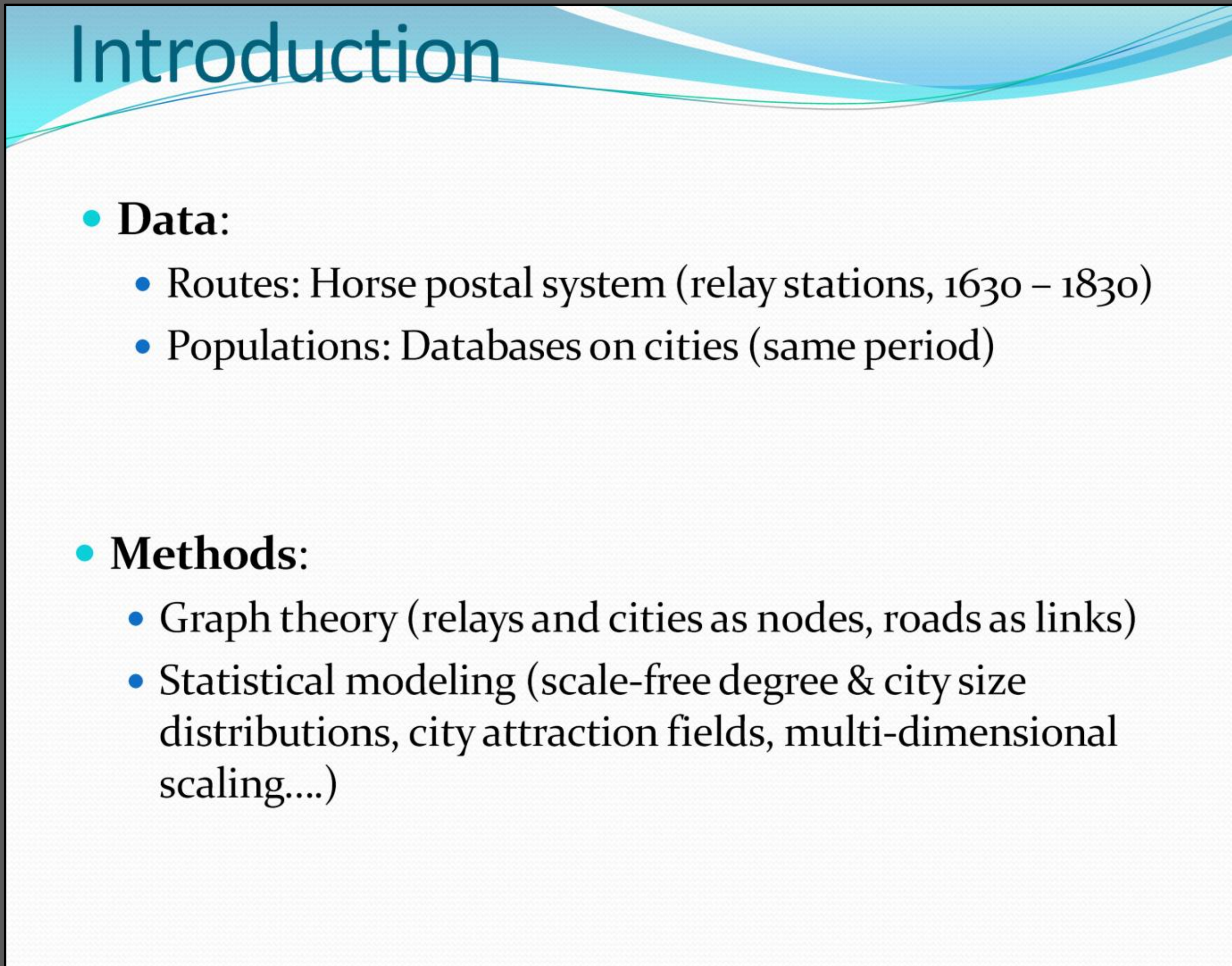
However, there are some evidences that the emergence of a national city-system could have occurred before the 19th century, i.e. before the industrial revolution. Empirical data show that there is a first period of urban growth, between 1740 and the 1789 Revolution. One can suppose that this growth is correlated with two other changes, the new road network and the colonial maritime trade.



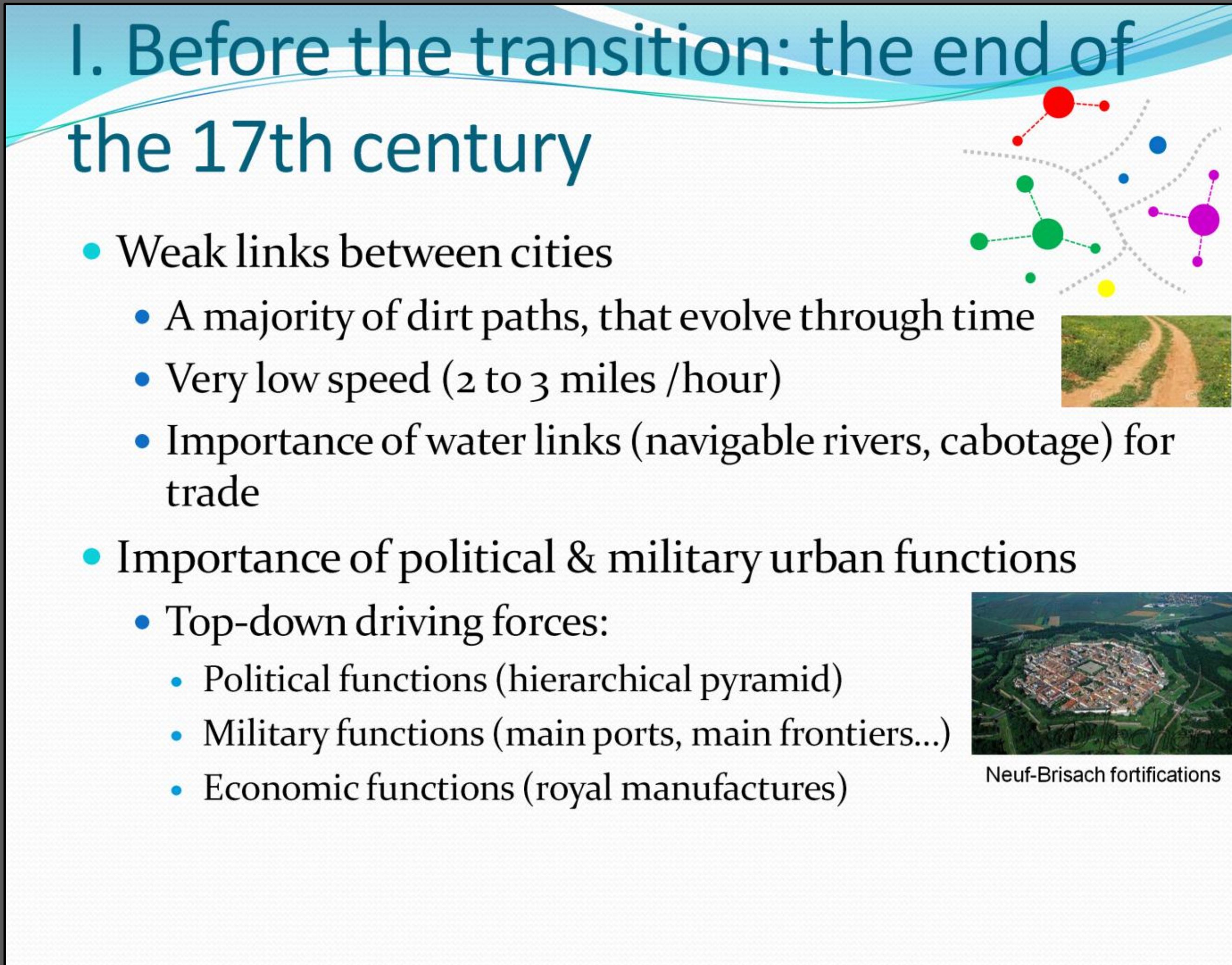
If the 17th and the beginning of the 18th centuries can be characterized by local and regional city networks, it is assumed that two different integration processes began to operate in the 18th century. First, increasing speed and the construction of paved/stone roads may have resulted in a "scale up in the network structure" (William Garrison 1990). We identify here a network integration process, allowing to go from local to global (national) scale. Secondly, as the major economic impulse based on the maritime trade reinforced the local activities of traders and merchants, in parallel with monarchy-driven activities, we identify a territorial integration process, allowing to go from global (monarchy) to local scale. Medium scale then appears as a necessary and intermediate link for joining these two scales, local and global.



In the Transmondyn project, we have chosen to focus on the urban transition of the 1730-1830's, i.e. the emergence of a national city-system before the industrial revolution. According to our hypothesis, Regime 1 (17^{th} cent.- 1730's) could be characterized by local and regional city networks and Regime 2 (1830's and after) by a major urban growth and concentration.

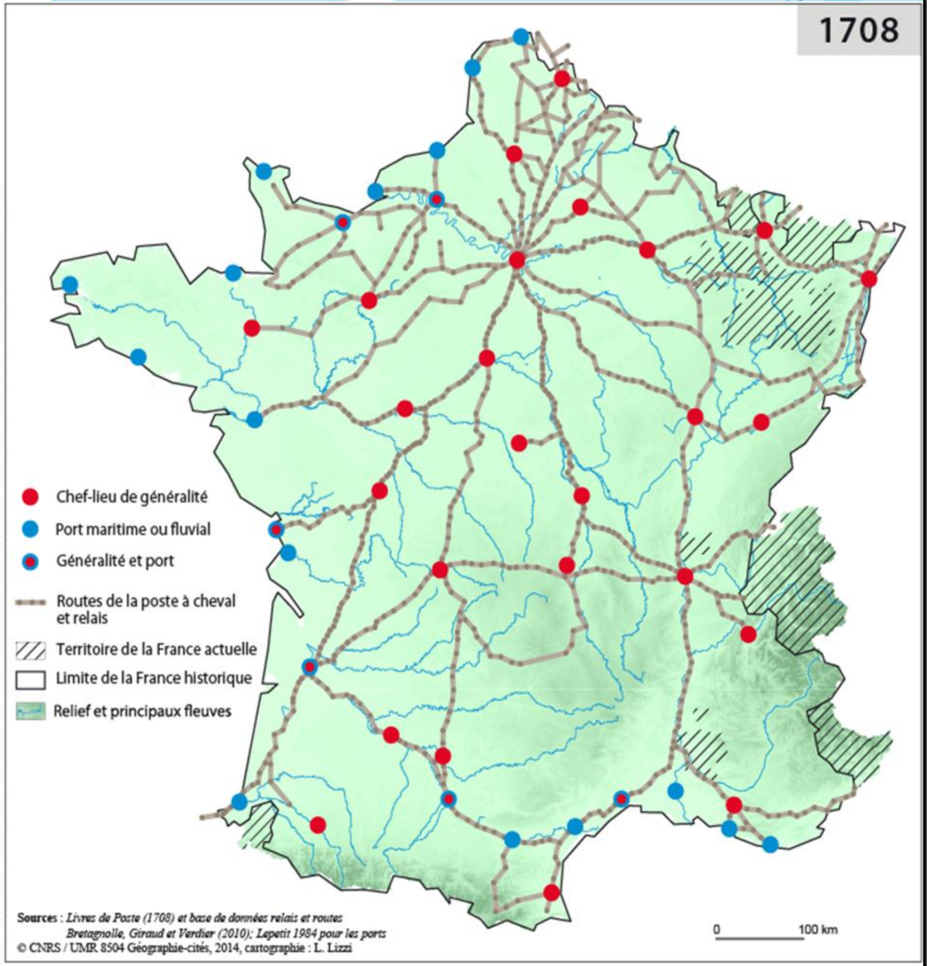


We mainly used two different sets of data, one about horse postal system and the other about urban populations. The postal roads are reconstructed from a series of relays, coming from the *Livres de* Poste (postal books). They give the succession of the relays where horses were changed. Each relay have then been georeferenced, in order to digitalize the postal roads in a GIS (Bretagnolle, Giraud, Verdier 2010). Concerning urban populations, we gathered databases constructed by historians (P. Bairoch, B. Lepetit) and national sources (1793, 1809 and 1831). These two sets of data have been processed in two different ways, first by using graph theory, second by using statistical modeling.

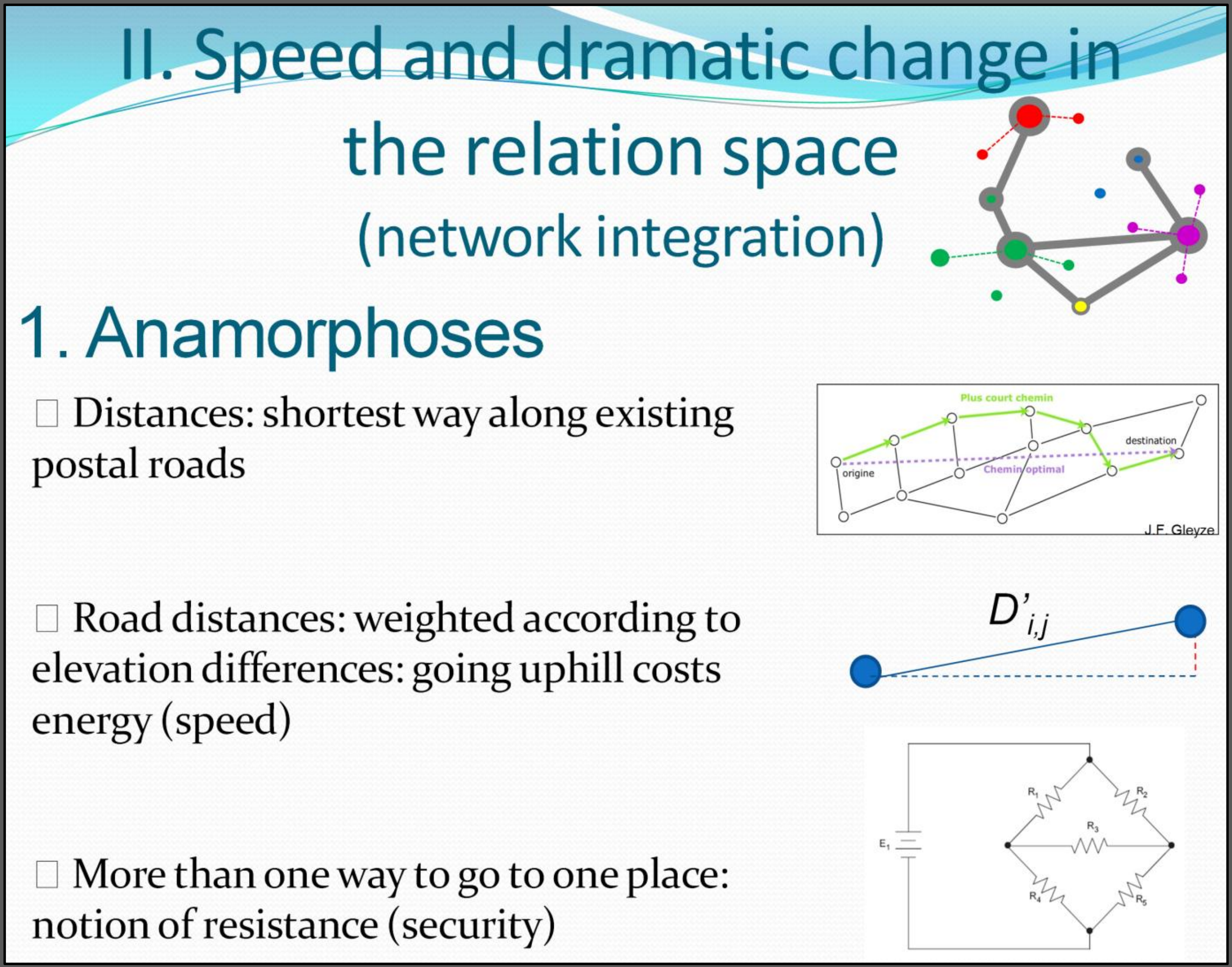


Regime 1 can be shortly described by two different sets of characteristics, regarding links and nodes. Concerning links, transportation networks are very lacunar. Continental transports are made with dirt paths, stoned or paved roads being very rare at that time. Speed is low and obstacles are numerous. When it is possible, men and products use water links. Concerning urban nodes, the driven forces come from political and religious functions. In this context, administrative, military and economic activities are the most dynamic (for instance, harbors, royal manufactures, military frontier places, regional chef-lieux). They are largely managed by monarchy, in a top-down way.

1708, Postal routes serving State administration and harbors

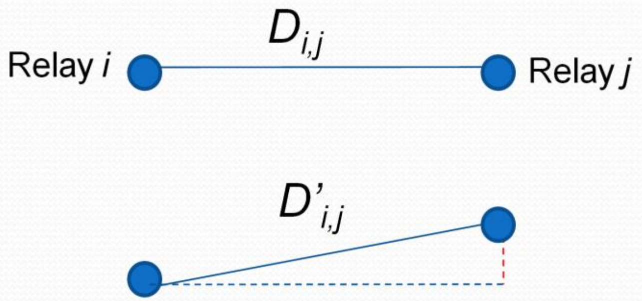


1708 is the first date considered in our postal roads Geographical Information System (it corresponds to the older postal book kept in postal archives). The map shows that the main function of the postal roads is serving state administration (chef-lieux de généralité, in red dots), harbors (in blue dots) and frontier places (especially in the North-East).



In order to explore the network integration process, we first focused on the impact of the new road network and the increasing speed on the French territory, especially on cities. We used the cartographic process of anamorphoses and considered network-distances (instead of the topographical ones, used on a classical map). In order to take into account speed (and considering the lack of historical data related to that point), we have weighted these network-distances by elevation (difference of altitude between two relays) and resistance (see below).

Impact of slopes on speed:
Weighting distance with elevation difference



$$\Delta = |z_j - z_i|$$

$$D'_{ij} = (1 + \alpha\Delta) D_{ij}$$

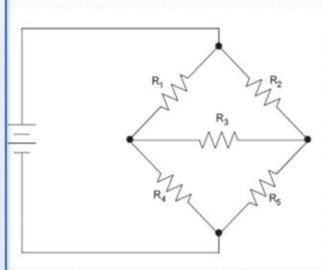
The elevation parameter is constructed by calculating pairwise elevation differences, then by increasing topographical distances according to a coefficient α which is a parameter of the model.

Distance versus Resistance

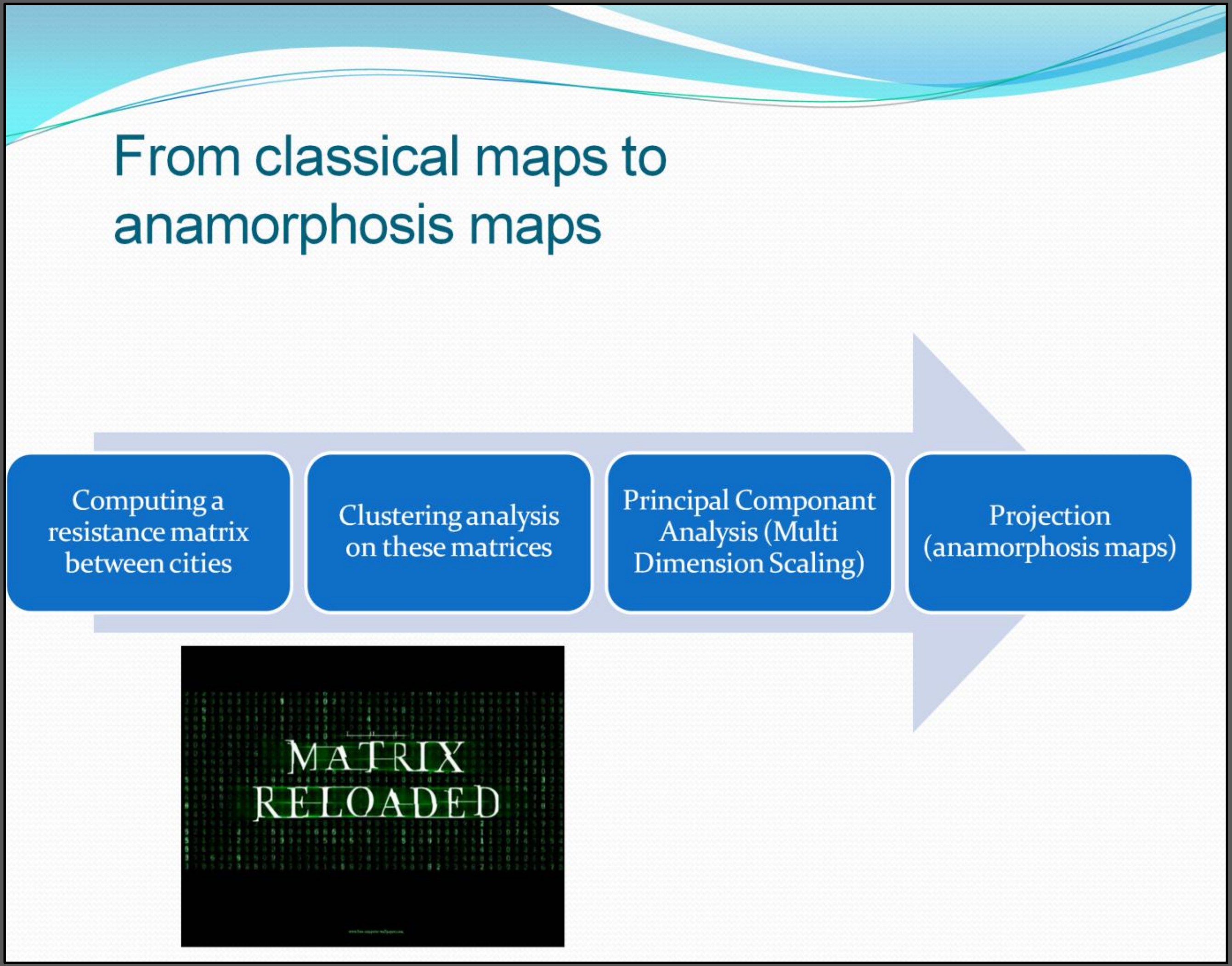
Both fluency and security of information transfer increase whenever several routes join two points.

The resistance, a notion from electric circuits, but relevant for water flows in tubes, formalizes this.

Resistances → add when in series
Conductances → add when in parallel

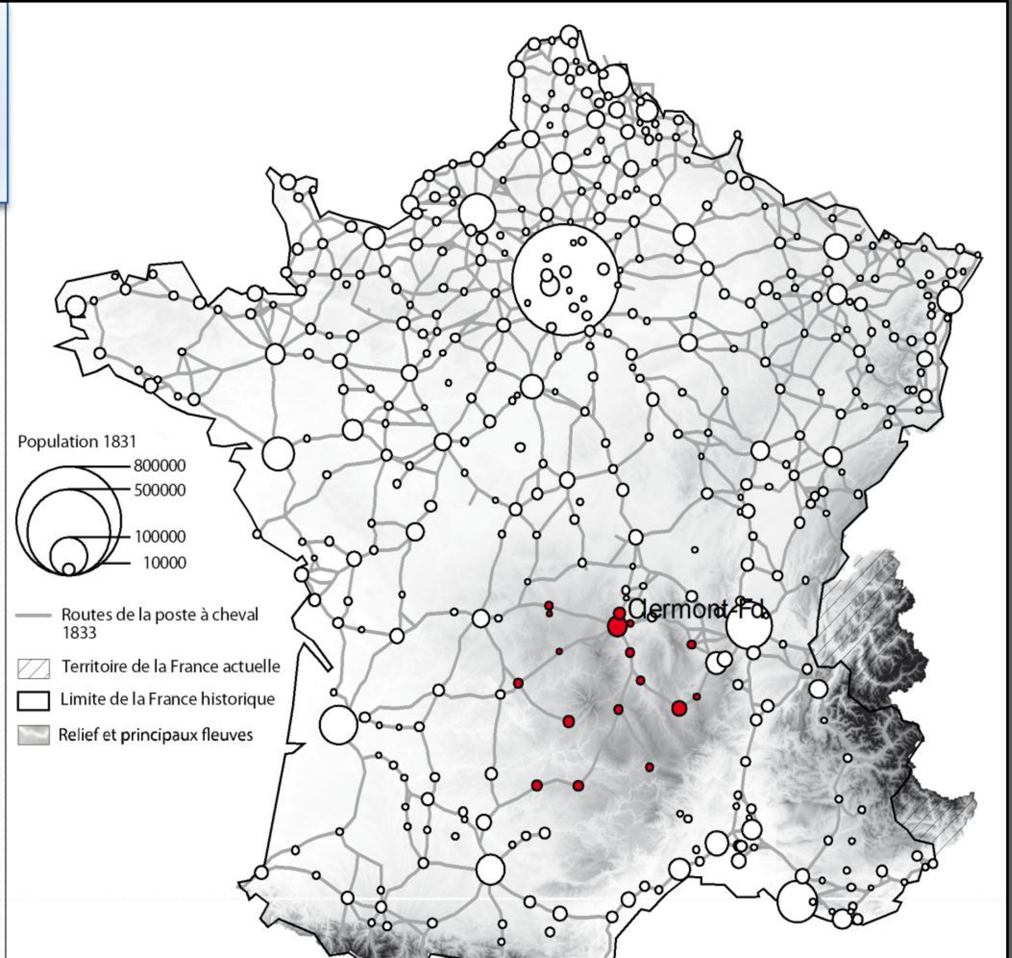


Resistance is a measure coming from electricity. It has been transferred in graph theory. The inverse of resistance (conductance) can be assimilated to connectivity, i.e. the existence of multiple paths between two nodes.



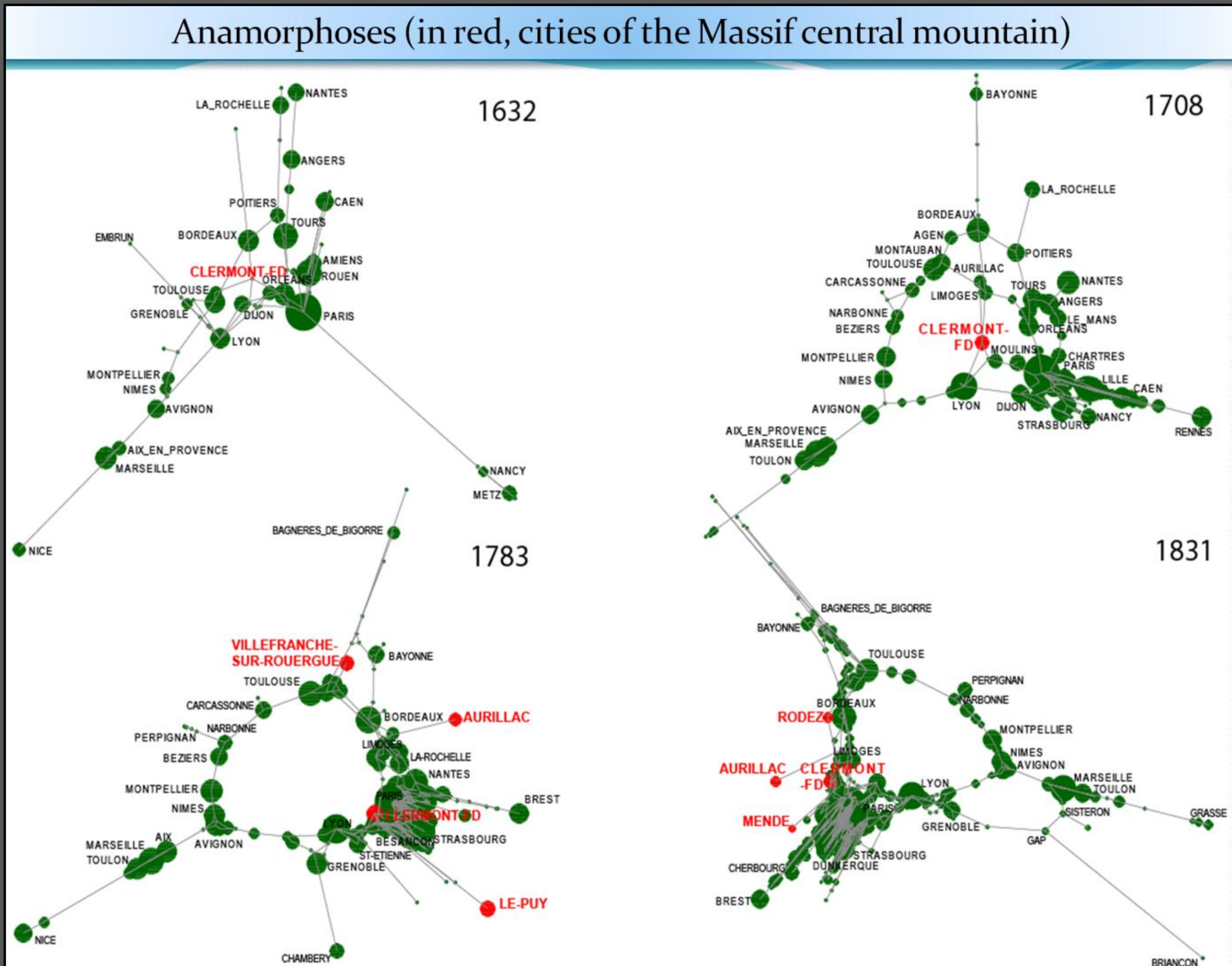
Different statistical data analyses were used to construct anamorphosis. First, one compute a resistance matrix between all pairs of cities. Then a clustering analysis is made on these matrices. A Principal Component Analysis is realized and results are projected. These projections are anamorphosis maps.

A classical map (in red, cities of the Massif central mountain)

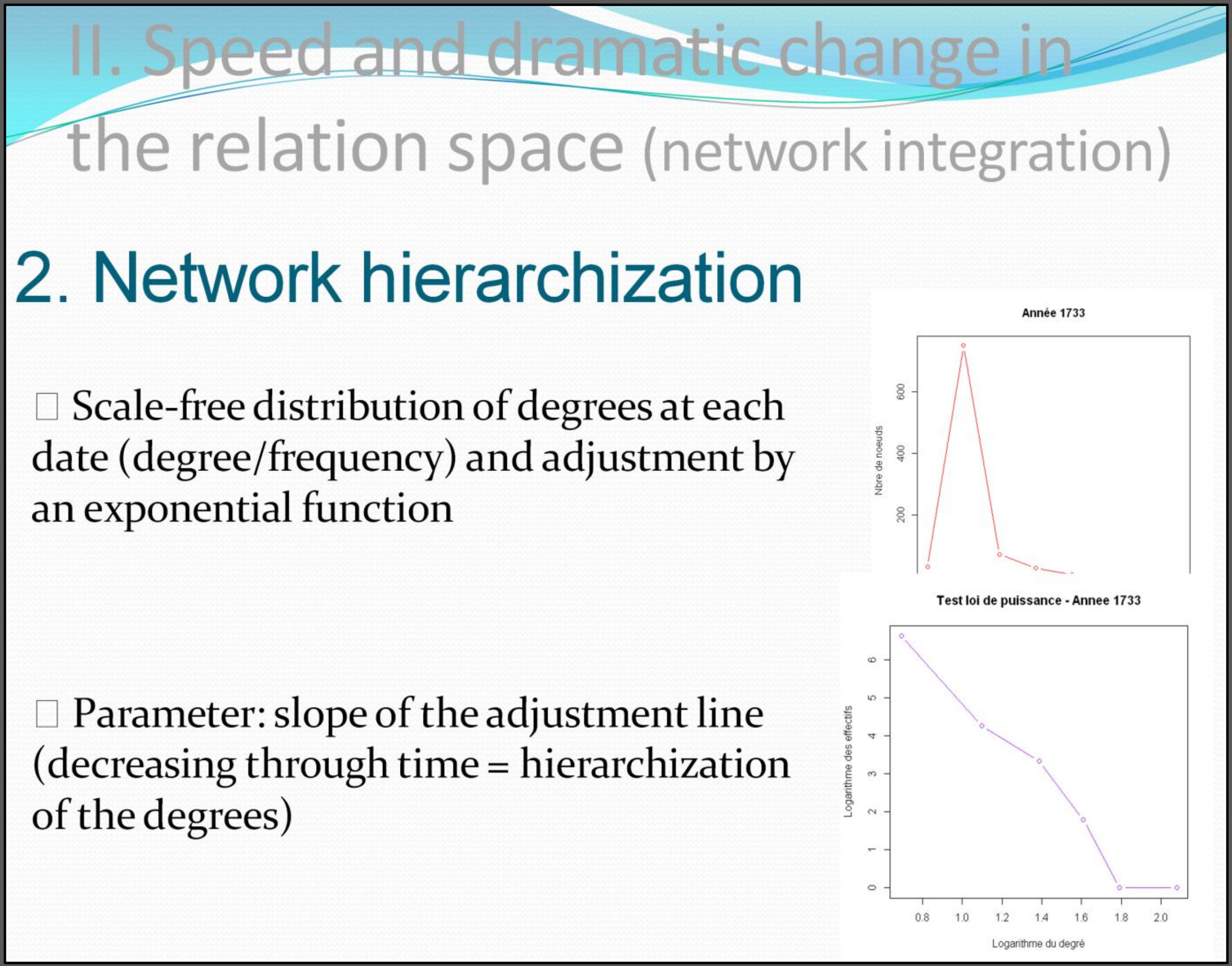


Sources : *Livres de Poste (1833) et base de données relais et routes Bretagnolle, Giraud et Verdier (2010); Lepetit 1984 pour les ports; Bulletin des Lois 1831 pour les populations; Nordman et al. 1989 pour les départements.*

In order to facilitate the comparison between an anamorphosis and a classical map, we have stressed in red the cities located in the central mountain of France (Massif Central).



We have included in our analyses the 1632 postal roads, given by the map from Nicolas Sanson. Results show that at this time, the relative positions of cities are not really affected by the postal network: Clermont-Ferrand, at the geographical center of France, is still at the center of the anamorphosis. However, from the beginning of the 18th century, the north of France (largely served by postal roads) becomes more and more shrinked whereas the south (much less served by postal roads) more and more dilated. In 1783 and 1831, the cities of Massif Central seem as far from Paris than the ones located at the opposite ends of the country, in Bretagne (west, for instance Brest) or Spain frontier (south-west, for instance Bayonne). The research of speed, which is characteristic of the period 1760-1770 (see Arbellot or Studeny) by improving infrastructures, reducing pauses or selecting the best breeds of horses, seems to create a new regime of communications. Reliefs and mountains are avoided, and the ancient pedestrian and mule regime is replaced by a rider and horse one.



The second statistical data analysis relates to the road network hierarchization. The hierarchy of the road networks relates to the form of the distribution of degrees. We are interested in the evolution of this form, i.e. the evolution in the level of contrasts between degrees. Each relay is characterized by its degree at each date (1 for cul de sac, 2 for stopover, 3 and more for crossroads). The distribution of degrees at each date is scale-free and can be adjusted by a power-law or an exponential one. We have chosen the exponential one and remove degrees 1, which are artificially reduced by the non inclusion of cabotage lines and foreign postal roads in our database. The slope of the adjustment line is used as a parameter describing the level of hierarchy between nodes. When the value decreases over time, it means than the level of contrasts between nodes increases.

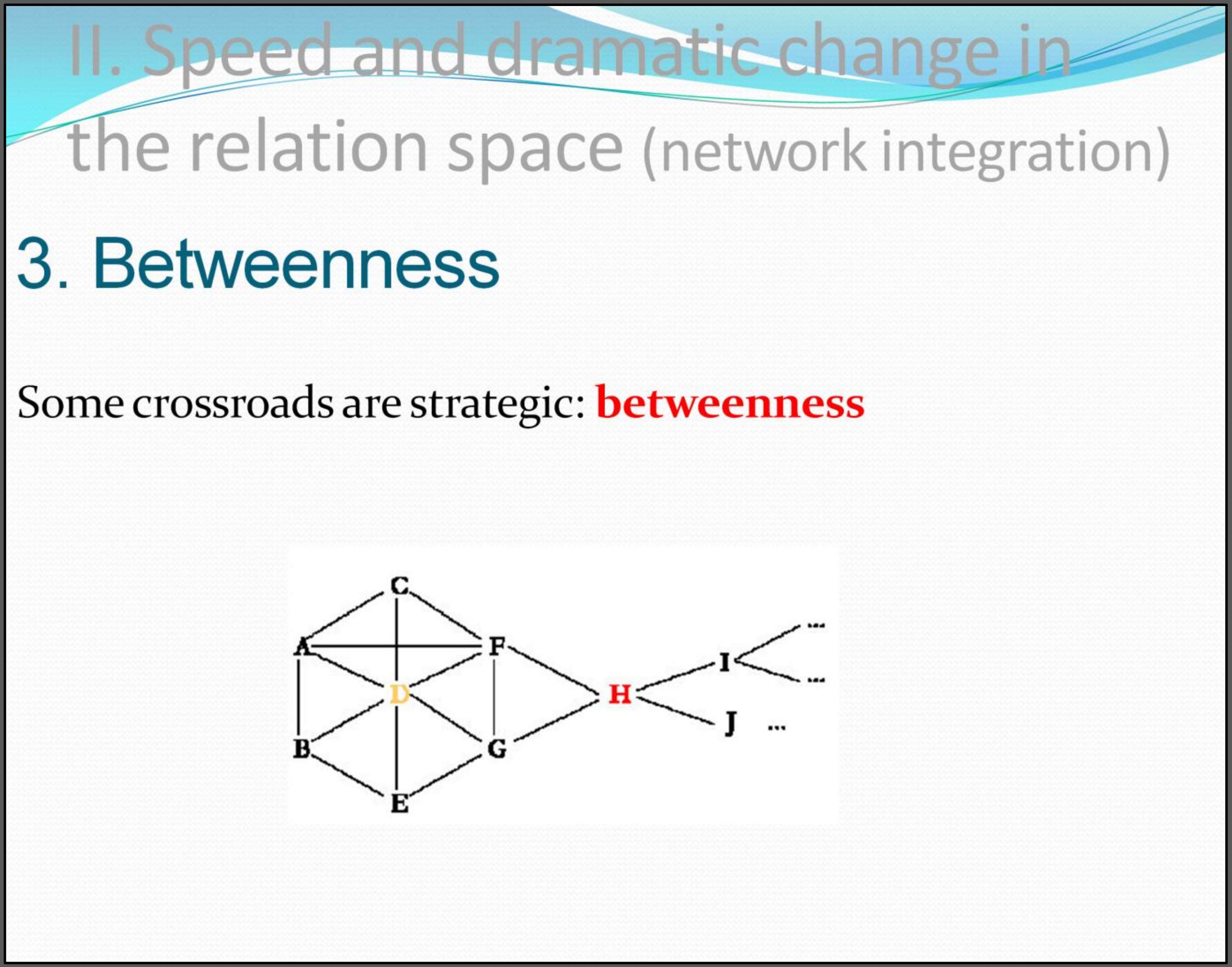
Results:
1. Hierarchization

	Slope of the adjustment line (absolute value)	Coefficient of determination R^2
1708	1.32	0.90
1733	1.13	0.86
1758	0.92	0.97
1783	0.89	0.97
1810	1.11	0.99
1831	0.90	0.98

2. Increasing degrees (1758-83)

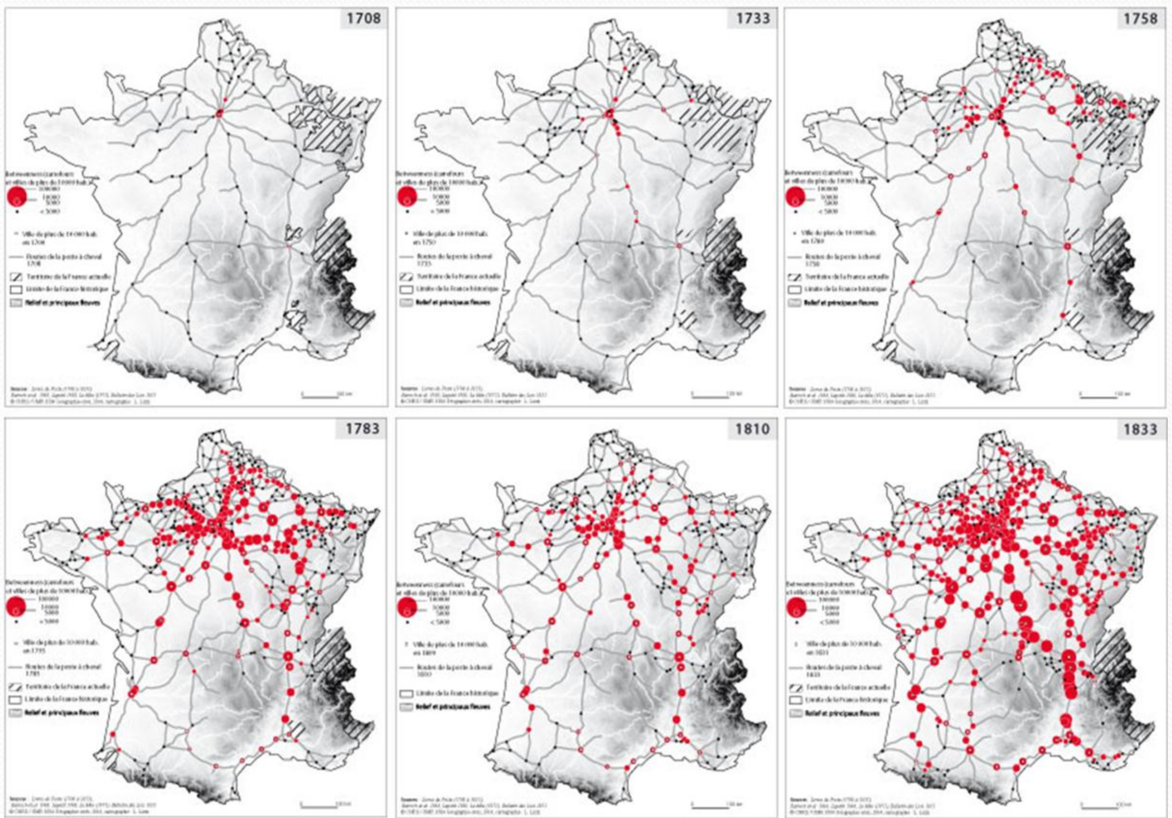
	< 10 000 inhabitants	10 000 - 25 000	**25 000 - 50 000**	**> 50 000 inhabitants**
Increasing degree	*Dreux (5-6), St-Avold (4-6), Melun (3-6), Dol-de-B. (2-6), Gisors (2-6), Dôle (2-6)*	Chartres (4-7), Abbeville (4-7), Beauvais (1-7), Verdun (5-6), Le Mans (4-6), Chalons-sur-M. (4-6), Saumur (2-6), Tarbes (0-6)	**Amiens (7-8), Rennes (5-8), Tours (4-7), Caen (5-6), Clermont-Fd (4-6), Dijon (4-6), Besançon (3-6), Orléans (3-6), Toulouse (2-6), Troyes (2-6)**	**Paris (9-10) , Rouen (7-9), Lyon (6-7), Strasbourg (6-7), Lille (6-7)**
Stability			Arras (7-7), Nancy (7-7), Metz (6-6)	
Decreasing degree	*Montdidier (7-5), Avesnes-sur-H. (6-5), St-Pol (6-4), Laon (6-4), Ham (6-3)*	St-Quentin (6-5), Cambrai (6-5)		

The evolution of the values of the parameter over time shows that the network is more and more hierarchized, except during the Revolution and imperial wars (characterized by a lot of road closures). For instance, between 1758, the most important crossroads are 6 to 9 degrees and in 1783 7 to 10 degrees. We have identified cities corresponding to these major and increasing crossroads. They correspond to the largest cities (Paris, Rouen, Lyon, Strasbourg, Lille), which are, in other words, the "tree roots" of the road network. The other large cities in France, that are not represented in the Table, are the major ports (Bordeaux, Nantes, Marseille).



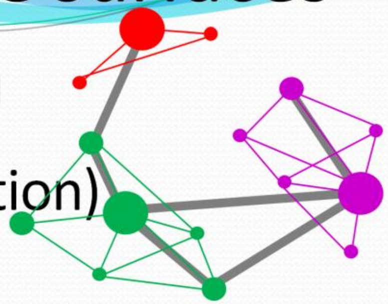
The third statistical data analysis that was done regarding the network integration process concerns the evolution of the betweenness. This index is one of the most used in graph theory. Its construction is very simple: all pairwise shortest ways are computed. Betweenness of a vertex is the total number of shortest ways passing through the vertex. It is related to the notion of a ‘cut’ in a graph: if high betweenness vertices are removed, the graph is no longer connected. Here, D and H have a high betweenness, higher for H than for D.

Betweenness centrality: from Paris to a variety of cross-roads (medium&large cities)



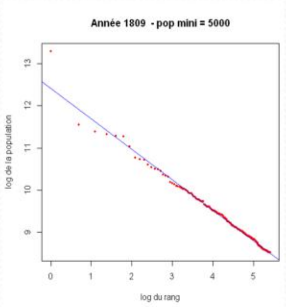
The values of the betweenness centrality have been mapped at the different dates. In the beginning of the 18th century, Paris is quite the only crossroad in France, whereas from the middle of the 18th century, other large cities (more than 10 000 inhabitants) have a high betweenness, especially along the road from Bordeaux to Paris (linking the Atlantic ports and the rest of France) and from Marseille to Paris and the North-Est (close to Belgium, Netherlands and North Germany, which constitute the economic gravity center of Europe at that time, also with England).

III. Emergence of exchange surfaces around medium cities (territorial integration)

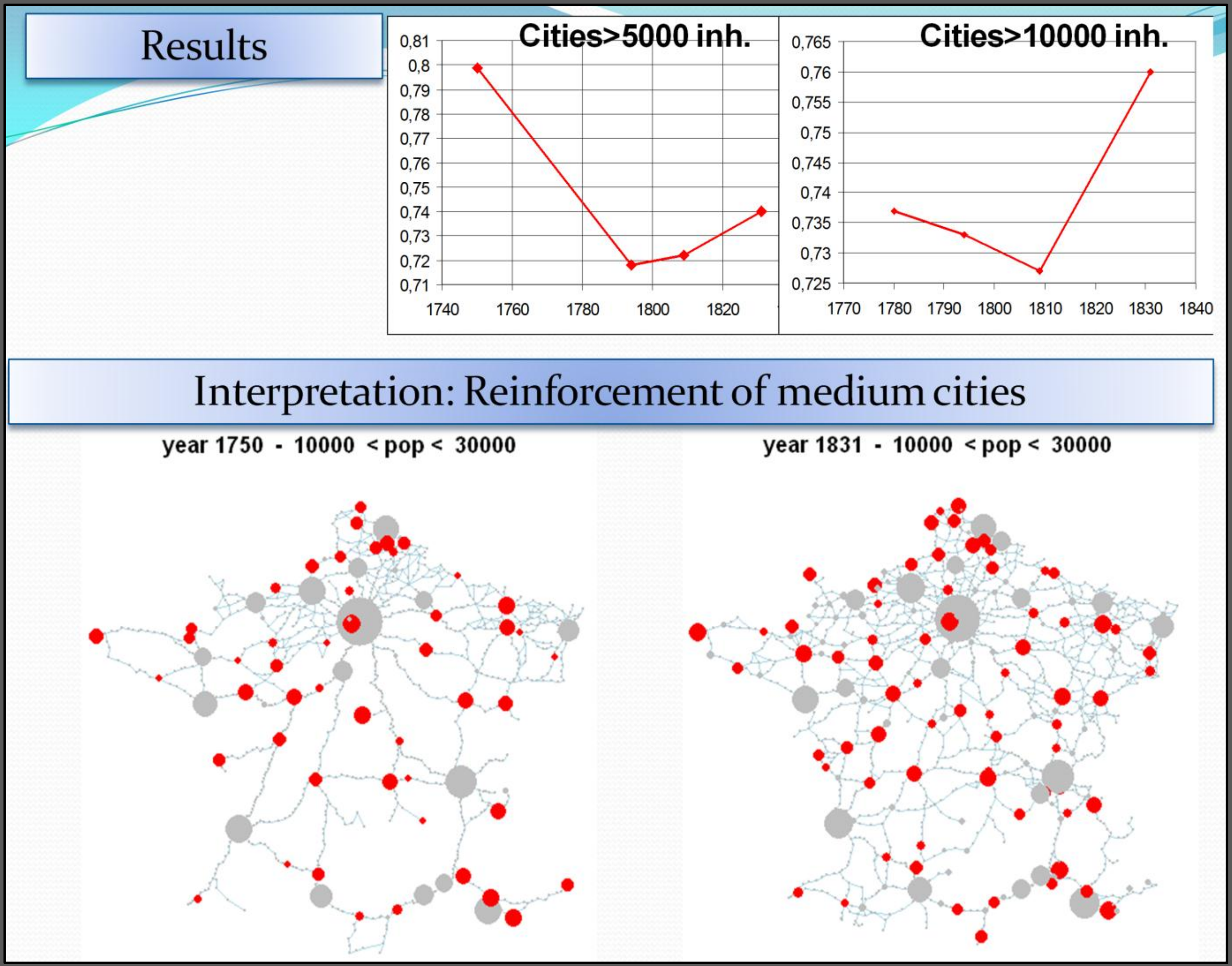


1. Medium-cities growth

- Scale-free distribution of urban population at each date (rank/population)
- Parameter: slope of the adjustment line (increasing through time = hierarchization of the cities)



In order to analyze the second integration process (the territorial one), we first focused on the medium cities by computing the slope of the rank-size graphs. As the distribution of urban population is scale-free and can be adjusted by a power-law function, we used the parameter of the adjustment line (in absolute value) as an index of urban concentration. When it increases, it means than the largest city grow faster than the average.

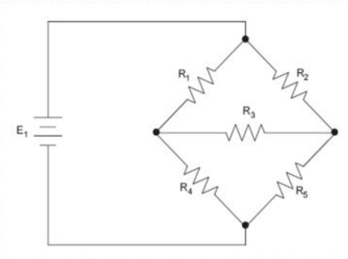


The evolution of the parameter through time enlightens decreasing hierarchical contrasts during the second half of the 18th century. This result can be interpreted when mapping medium cities (in red) in 1750 and 1830. Medium cities are more and more numerous and distributed more and more evenly in the territory. Our hypothesis (already formulated by B. Lepetit, 1988) is that their reinforcement during the second half of the 18th century explain the decreasing hierarchical contrasts of the city-size distribution.

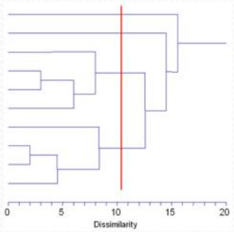
III. Emergence of exchange surfaces around medium cities (territorial integration)

2. Invention of connectivity (road loops)

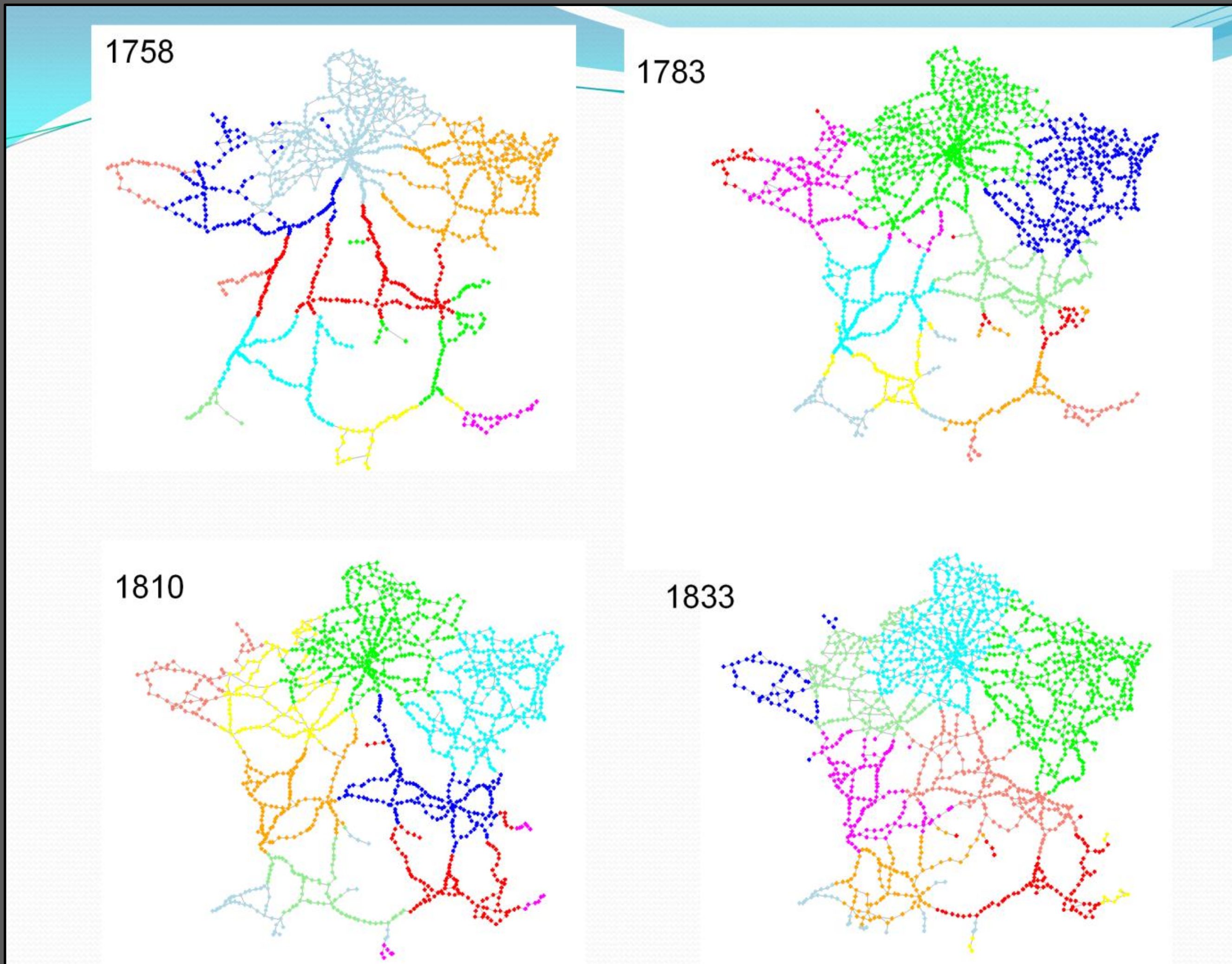
- Importance of loops



- Clustering analysis of the resistances: is there a regionalization of these loops ?



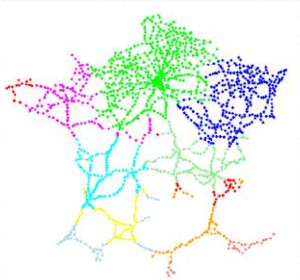
We then analyzed the emergence of road connectivity during the 18th century, which represent a major innovation. At that time, roads are often cut by flooding, deep ruts, banditry and robbery, and loops reduce uncertainty of the travel. The resistance measure allows statistical and geographical analyses of the loops.



A clustering analysis of the resistance in 10 classes and the mapping of the results show that there is a gentle spread of loops from the North and North-East (from 1733 to 1758) to the Center of France (1783) then the South (1810 and 1833).

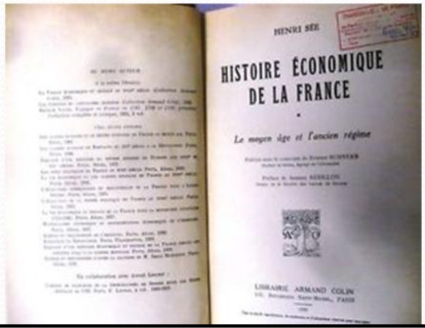
III. Emergence of exchange surfaces around medium cities (territorial integration)

3. Interpretation of connectivity: bottom-up processes (economic & political)



- Empirical analysis of the main road loops that emerge in France

- Historical sources and story telling (work by economic historians)


HENRI SÉE

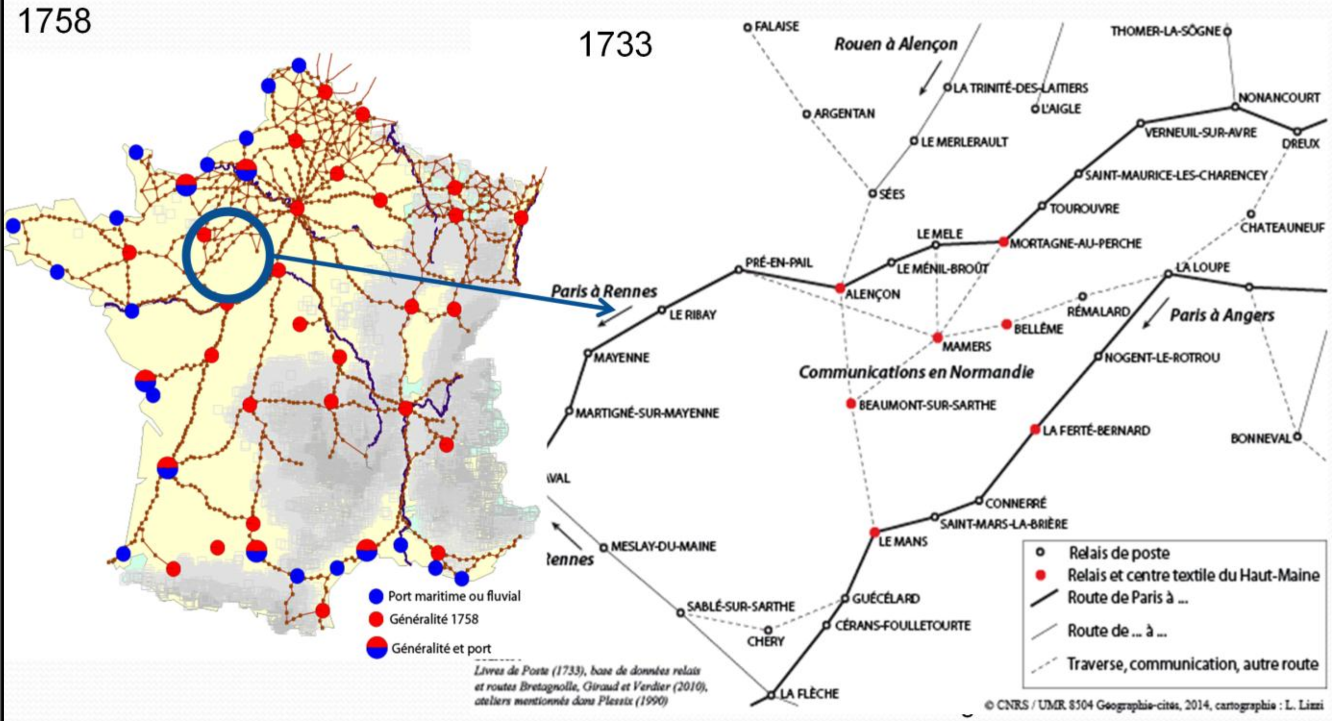
HISTOIRE ÉCONOMIQUE DE LA FRANCE

Le moyen âge et l'ancien régime

LIBRAIRIE ARMAND COLIN

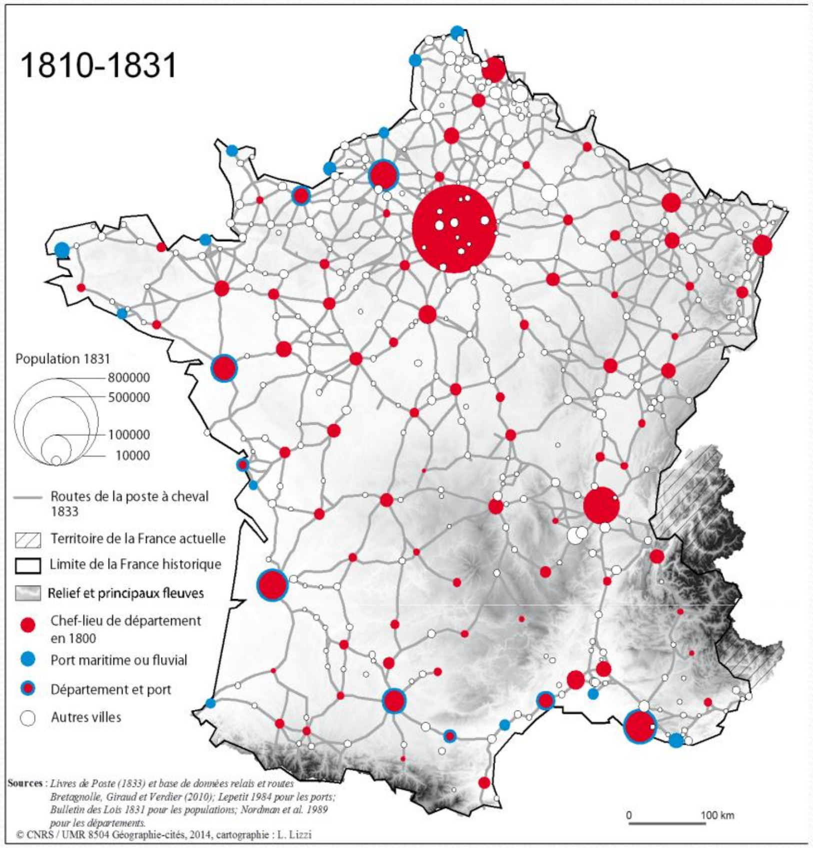
In order to better understand the emergence of loops, we used different works from historians and tried to find economic and/or political explanations.

a) Correlation between small loops and trade areas

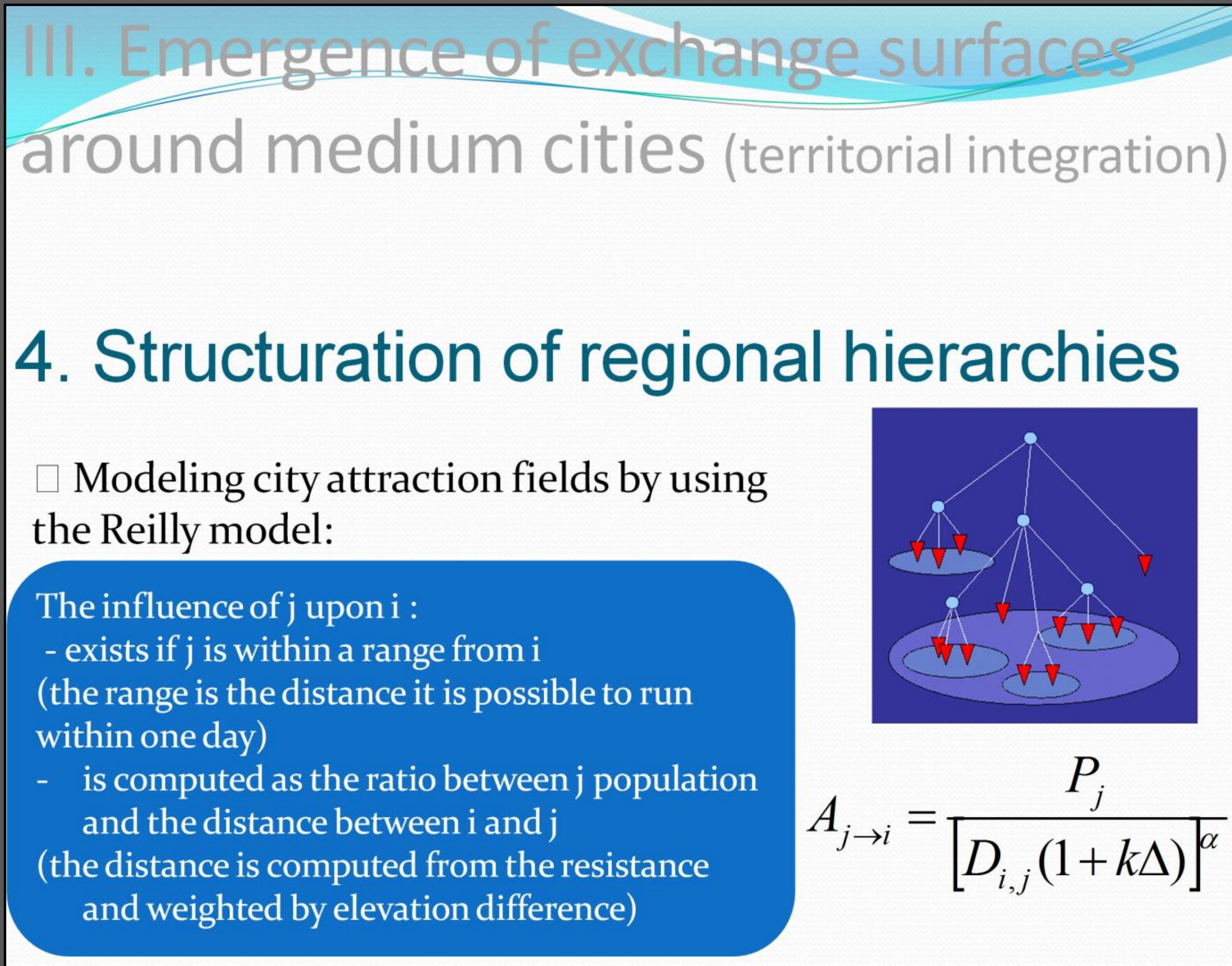


We first analyzed the small loops that emerge in the North, especially in the Basse-Normandie (located in the blue circle on the left map). This region is characterized by rural industry and small textile centers. When looking at the names of roads in the postal book of 1733, we noticed the presence of a particular type of roads, named "secondary", "other roads" etc. (represented in dot lines on the right map). These secondary roads are particularly important in Basse-Normandie and serve the small textile centers (in red). One can assume that the postal network was not only used by monarchy for state administration but also by merchants and traders for exchanging information with Atlantic ports and the main export-import locations.

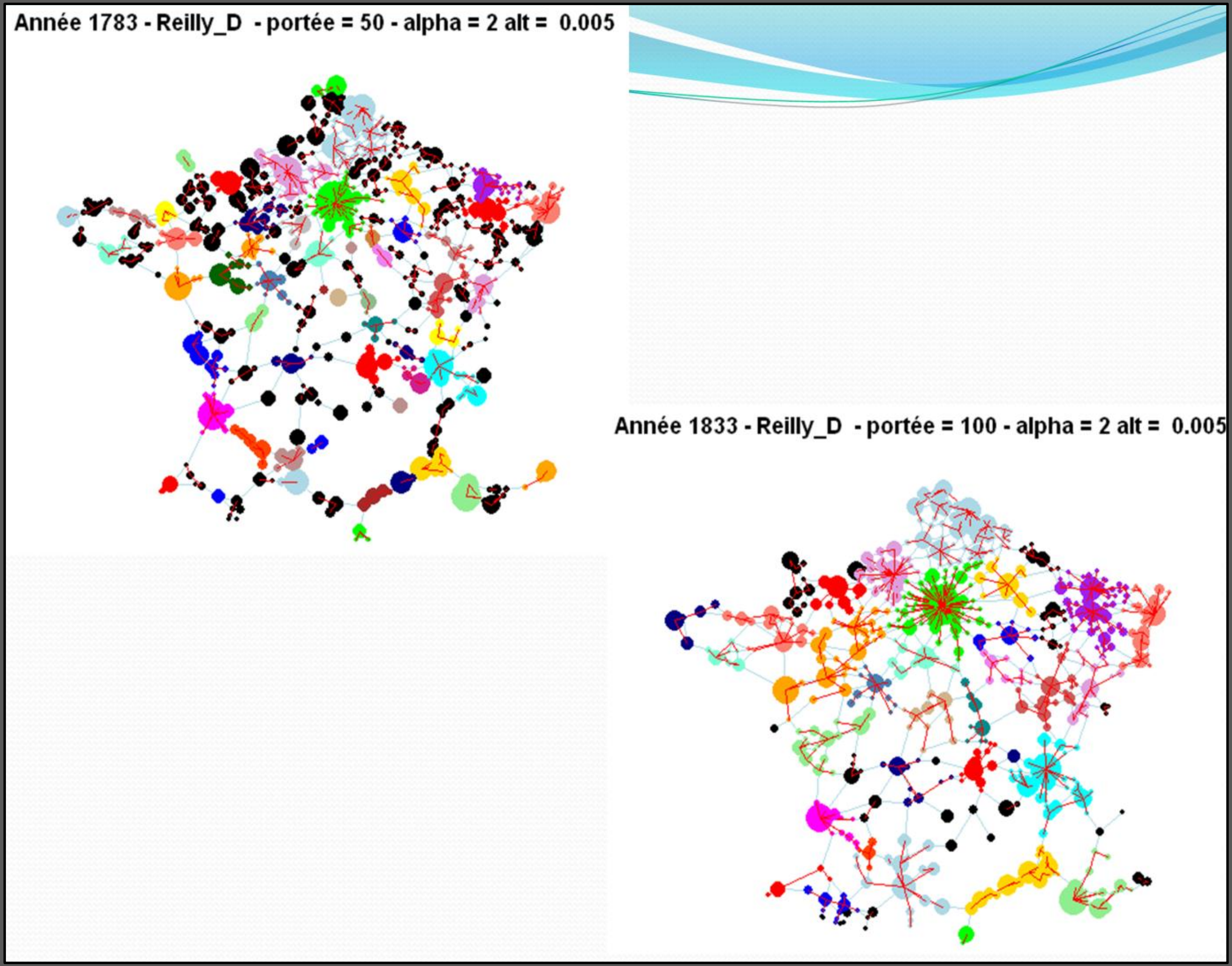
b) Correlation between large loops in the South and the new administrative structure of the Revolution (bottom-up)



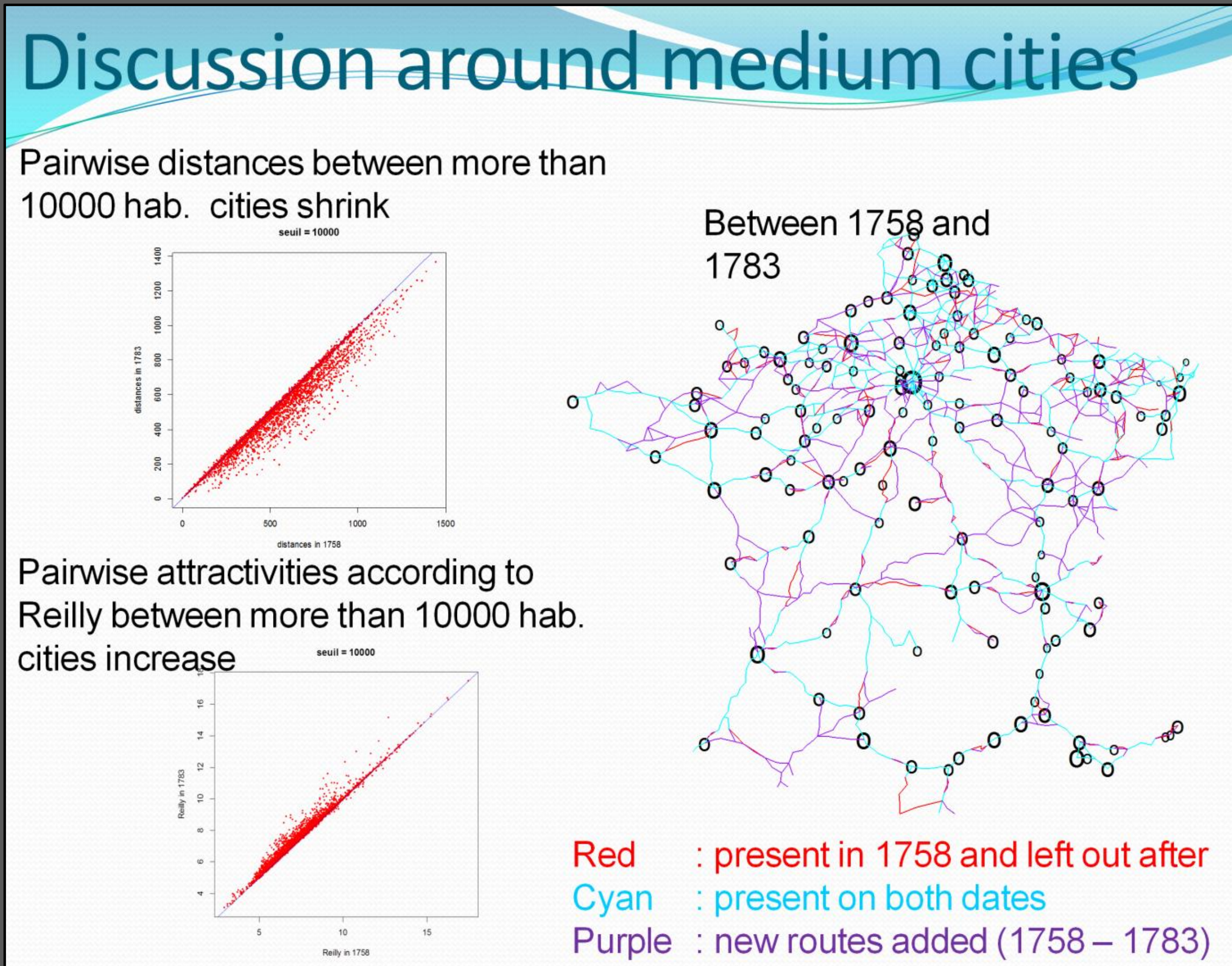
We then analyzed the large loops of the South that appear later, in the end of the 18th century. Cities served by the new roads forming these loops are, for most of them, the new chef-lieux of departments formed by the Revolution and the Convention Assembly, represented in red on the map. One can then assume that part of the southern loops are due to the new postal roads that was constructed after the Revolution in order to link the new chef-lieux, especially in the Alp and Massif Central. A new function for the postal network is now to serve equally the new citizens of the French territory, in a bottom-up way.



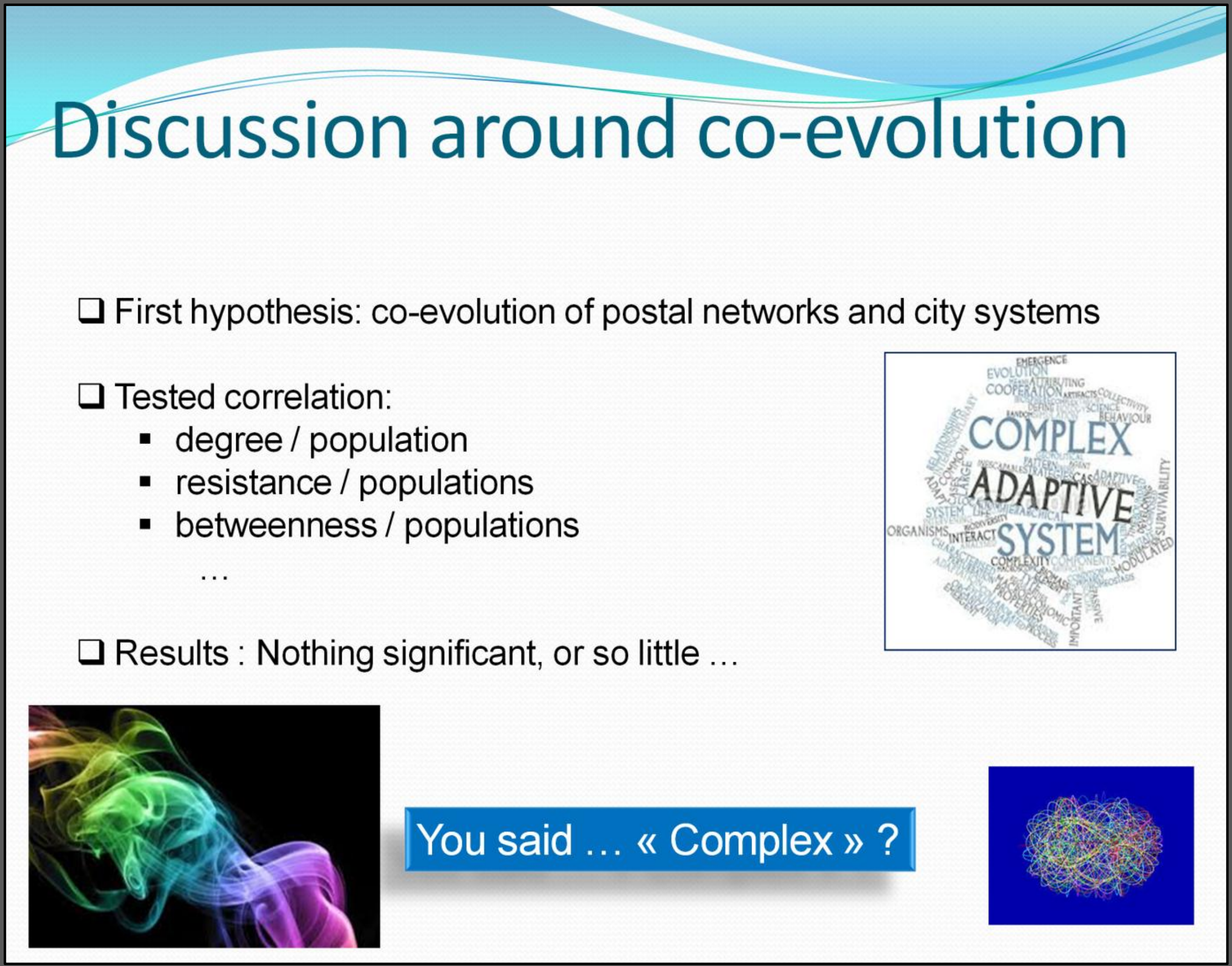
We finally analyzed the progressive structuration of regional hierarchies in order to better observe the emergence of city-systems and the role of the medium cities. In this context, we worked on regional networks by modeling at different dates city attraction fields, using a Reilly model (1931). In this model, the influence of a city j upon a city i is computed as the ratio between j population and the distance between both cities. In order to delineate a regional networks, a maximal range is given by a parameter, the distance that is possible to run within one day. Maps are then constructed by linking each tree root and the different cities under its influence, forming a sort of “urchin”.



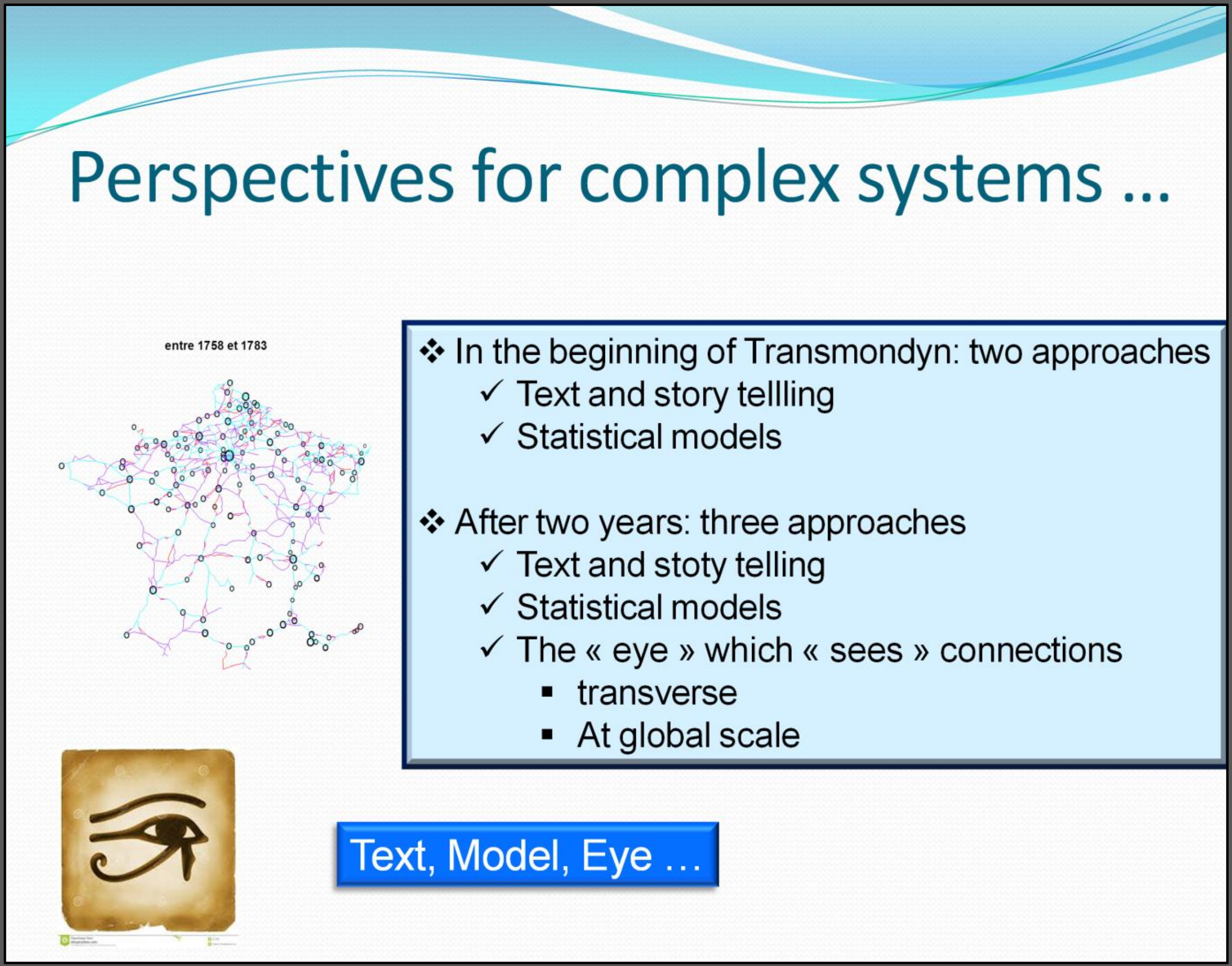
Results are mapped for two different dates, 1783 and 1833. In 1783, the range parameter is 50 km and in 1833 it is 100 km, according to empirical observations made by Guy Arbellot. In 1783, many cities are « heads » and no clear hierarchy appears. There is a collection of stars around heads. In 1833, the contrast between North and South is huge. In the North, space is tiled with regional hierarchies (for instance Paris, Strasbourg, Lille, Nantes etc…), which could reflect a process of hierarchical integration and the formation of "systems of cites" (Lepetit 1988). In the South, one can observe the paucity of evolutions. Apart from Lyon and Toulouse, we still have stars around heads, forming the primatial organizations that were characteristic of Regime 1.



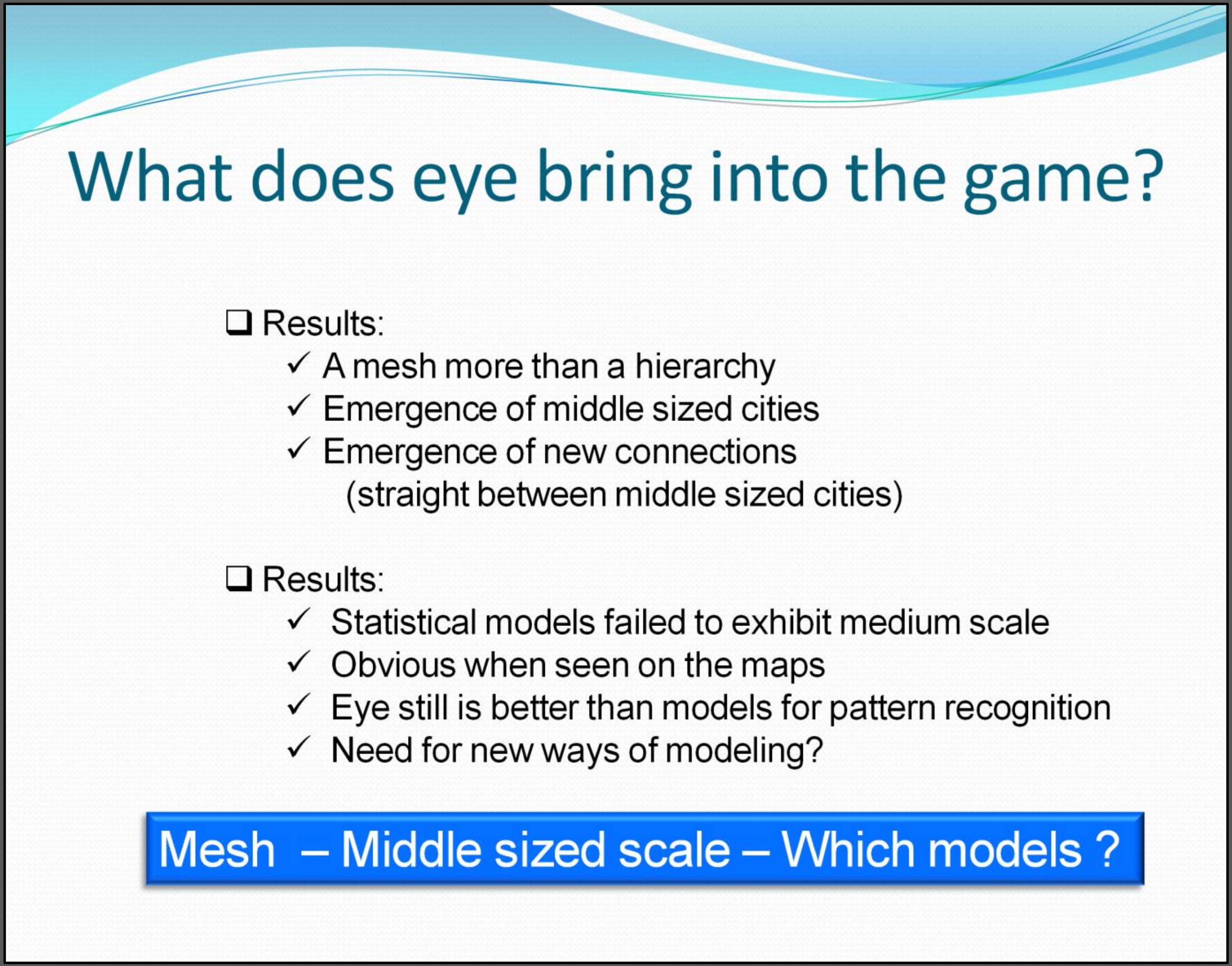
In order to discuss the results of Transition 9 and the emergence of a national city-system in France, we focus first on the role of medium cities. The colors of the roads in the map indicate which route have changed between 1758 and 1783 (closed, in red, opened in purple), or not (in cyan). One can see that entirely new routes have been opened, especially between distant middle-sized cities, without going over a larger city. This can be seen in top left graph, where one dot is one pair of cities of populations larger than 10 000 inhabitants each, in x axis their distance in 1758, and y axis in 1783. One notices that most of points are below the diagonal, and many far below. This means that the distance for such pairs has significantly decreased. The same plot is shown below with Reilly index of attraction, which instead increased significantly. Then, the route network evolves in a way that middle sized cities are pairwise better connected, which suggests the development of a better connected national network.



Secondly, we put into perspective our initial hypothesis in the Transmondyn project, which was co-evolution of postal networks and city systems. For a long time, we had looked for a correlation between populations and either betweenness or degree. Most of the tests were unsuccessful. Previous result suggests why it can be more complicated than a simple correlation between elements of city systems and route networks: the link encompasses knowledge of both whole systems, and not part by part. This replaces part of the work into the framework of complex systems, or even complex adaptive systems, where simple correlations are not enough to grasp what builds the observed patterns.



In fact, in most of our studies, we have heavily relied on maps, and interpretations of them. Some interpretations were quantitative, but some still by eye inspection. The change in opening and closing routes is one example. But urchins from Reilly index, or role of neighborhood for clustering according to resistance distribution are some others. Then we must add the eye beside narratives and models as tools for deriving an explanation.



It is easy to specify some domains for which visual inspection is far better than modelling. Several of them deal with pattern recognition (how to recognize a face, for example). Here we exhibit some patterns which were proposed in this study by visual inspection of maps or graphs. They all emphasize the emerging role of middle-sized cities as structuring elements, and medium scale as far as distances are concerned (neither the neighborhood nor the whole network). There exists some indices for the global network structure (e.g. connectivity), or neighborhood (degree per node). There is a need for deriving indices of medium scaled structures and pattern. Next step, in the long haul, is to have some models which enable some progress into this direction.