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Alain L'Hostis

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The shrivelled USA: Representing time-space in the context of metropolisation and the development high speeds

Alain L'Hostis
Université Paris Est
LVMT
Inrets
20 rue Elisée Reclus
59666 Villeneuve d'Ascq, France
tel : +33 (0)3 20 43 84 98
fax : +33 (0)3 20 43 83 59
lhostis@inrets.fr

Abstract

On the one hand the present globalisation process has only been made possible through a reduction of time-distances allowed by high speeds, and particularly through the development of the air mode. On the other hand the metropolisation process seen as the urban counterpart of globalisation is deeply associated with the development of air platforms.
Understanding distances between places is a fundamental task for the geographer, while the representation of distances constitutes one of the major functions of cartography.
Among the types of maps invented to represent time-space anamorphosis have been supplemented in the 1990's with time-space relief cartography. This paper proposes a representation of the time-space relief of the USA considering terrestrial and air modes. This last point constitutes a key innovation among this type of cartography, giving the possibility to build a representation of global time-space. The metaphors associated with the images proposed are then discussed evocating the shrinking, the crumpling and finally the shrivelling of time-space. The shrivelling metaphor renders account of the complicate contraction/dilatation movement that thigh speeds provokes on space and allows for a rich interpretation of the time-space relief map of the USA in the perspective of the processes of globalisation and metropolisation.

Keywords

Time-space cartographic representation; globalisation; metropolisation ; shriveling.

Introduction

On the one hand the present globalisation process has only been made possible through a reduction of time-distances allowed by high speeds, and particularly through the development of the air mode. On the other hand the metropolisation process seen as the urban counterpart of globalisation is deeply associated with the development of air platforms. Both phenomenons are intrinsically linked to the formation of distances, and especially time-distances.
Understanding distances between places is a fundamental task for the geographer, while the representation of distances constitutes one of the major functions of cartography.
Among the types of maps introduced to represent time-space anamorphosis have been supplemented in the 1990's with time-space relief cartography. We propose in this paper a representation of the time-space relief of the USA considering terrestrial and air modes. This last point constitutes a key innovation among this type of cartography giving the possibility in

the future to build a representation of global time-space. The metaphors associated with the images proposed will then be discussed evocating the shrinking, the crumpling and finally the shrivelling of time-space.

1. Representing distances

We want to develop in this paper a reflection and a proposal on the representation of the contemporary global time-space, in the light of the double movement of metropolisation and globalisation.

To understand the present global space it is necessary to underline the major role played by high speeds in the structuring of metropolitan spaces. These high speeds have allowed the development of communications at the global scale. But in the mean time, high speeds operate a dramatic selection of places.

While this movement highlights the high places of global communication, the secondary networks and spaces remain present in the interstices. And a key point in the formation of global time-distances is the fact that these secondary networks are disqualified when compared to the main high speed networks.

In view of these phenomena the recent literature insists on the differentiation of space where global functions can be located in the close spatial neighbourhood of spaces of exclusion and derelict (Graham and Marvin 2001).

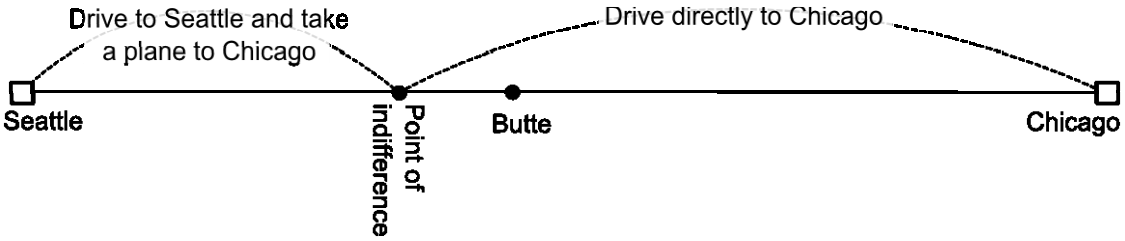


Figure 1 : the phenomenon of spatial inversion

But how to represent this complicated set of networks and relations in space? To tackle this question means considering the broader perspective of the representation of distances. In this field Bunge has stated that basically two ways are available "whether representing complicated distances on simple maps, whether representing simple distances on complicated maps" (Bunge 1962).

In his classical example of the complicated relations in space generated by contemporary transport means Bunge considers the movements from intermediary space to higher level cities with a trip from somewhere in the Montana to the metropolis of Chicago. The articulation of transport modes, here cars and places, implies in this example that the shortest path in time space takes a completely different shape beyond and after a particular point of indifference. Leaving from Butte would mean driving directly to Chicago, while starting from somewhere closer to the Pacific coast involve a trip by car to Seattle followed by a flight. This phenomenon of spatial inversion that follows an intuitive logic from a transport perspective provokes a disturbance in the order of proximities. If we refer to Cauvins's formalism (Cauvin 1996), while the Rocky Mountains are located between Seattle and Chicago in the chorotaxic space –the usual geographic space- their position in the functional space is different: in the transport space it is Seattle that stands between the Rocky mountains and the Great Lakes.

The identification of the phenomenon of spatial inversion constitutes a key justification of the research of new representation of time-space that would render this complicate set of distances. It is a direct call to complicate the map in order to allow the representation of distances that would be simpler to read.

In this perspective, time-space anamorphic cartography is the first proposal in which one moves the locations in order to better respect time-distances. An example is given by Shimizu

showing the contraction of Japan due to the development of the high speed train networks between 1962 and 1992 (Shimizu 1992). In the field of the representation of distances, anamorphosis belongs to the type of cartography defined by Bunge as simpler distances on a complicated map. Two informations on time-distances can be read from such a representation: the overall space contraction and the local deformations produced by high speed lines. If the new transport networks had been characterised by homogeneity and anisotropy the shape of the external borders of the country would have remained unchanged, only size would have been reduced. All the distortions from the usual and conventional figure of Japan indicate directions privileged by the shape of the networks. The literature on networks has abundantly expressed the idea that modern transport provokes heterogeneousness in space (Dupuy 1991; Castells 1996; Graham and Marvin 2001).

This model however is subject to limitations (L'Hostis 1996; L'Hostis 2003; L'Hostis 2007). The major critic to the application of anamorphosis to the representation of distances is the fact that if two locations, for instance two cities, are getting closer due to a new transport link this does not mean that the space in-between is also gaining in accessibility. Toll motorways are examples of the "tunnel effect" of some infrastructures where the limited access points reduces the accessibility gains to a set of subspaces and is not distributed evenly alongside the line (Plassard 1976). This phenomenon is even more pronounced in the case of high-speed rail (Mathis 2007) and is one of the major characteristics of the air mode (Haggett 2001). Furnishing an illustration of this limitation, the phenomenon of spatial inversion can not be read from the anamorphic map because of the principle of the preservation of the order of proximities which can be found in most methods developed in the literature (Shimizu 1992; Spiekermann and Wegener 1994; Clark 1999; Kotoh 2001).

Displacing the locations on the map is not the only way in which distances can be represented. The idea of drawing the transport lines between places in such a way that different distances are shown was introduced in the 1980's (Plassard and Routhier 1987; Tobler 1997). In the example proposed by Tobler location of cities and network nodes remains unchanged as compared to their usual cartographic position. The length of roads between the nodes is displayed under the form of a spring, the intensity of the tension indicating the sinuousness of roads unevenly distributed in this mountainous area in the Western Colorado. In this model one can obtain the information on the difficulty to link two places by reading the *visual length* of the links. The notion of visual length was introduced (L'Hostis 2003) to render account of the capacity of a reader of a map to extract the information on the length of a route from the analysis of the shape of the path. A straight segment can be converted in kilometres through a direct use of the scale, while a sinuous curve will give the information of a longer road. This principle is used in the spring map to express the idea of privileged and handicapped directions.

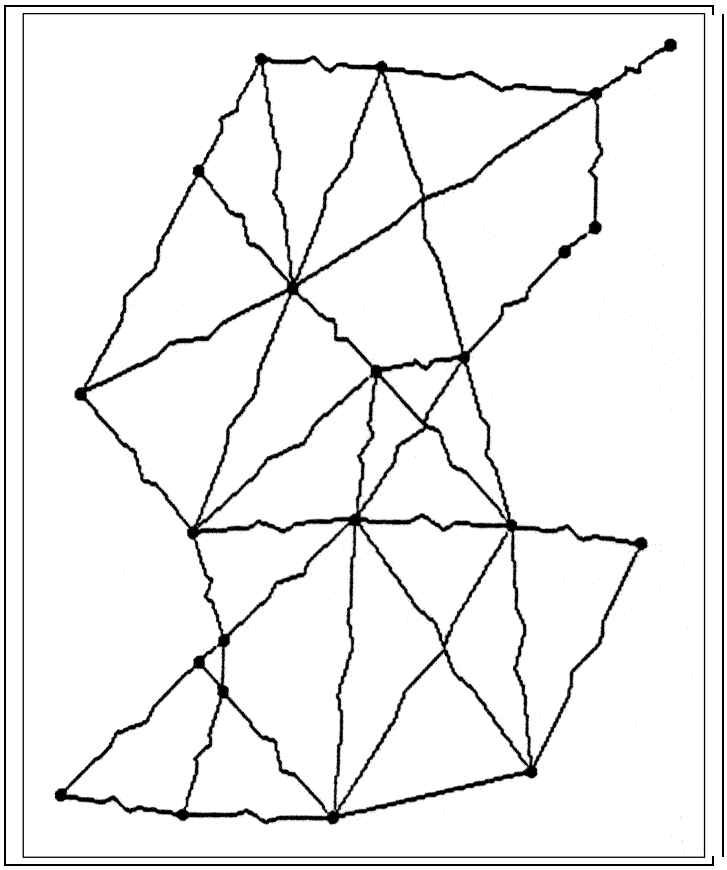


Figure 2 : spring map of roads in western Colorado

The spring map model can indicate shortest directions in space. Being a non-Euclidean representation it displays the idea that shortest paths often differ from the straight line. In this perspective, it constitutes a possible proposal to the call to non-Euclidean geography (Golledge and Hubert 1982; Müller 1982). More recently but in the same direction a model has been formulated to introduce a three dimensional surface that allow the representation of different speeds in urban space (Hyman and Mayhew 2004) .
Sharing a principle of construction similar to that of the spring map, the time-space relief map was introduced in the 1990's (Mathis, Polombo et al. 1993; L'Hostis 1996; Mathis 1996). This type of representation preserves the location of places but exploits the resources of the third dimension to draw the various speeds and the corresponding time-distances in a multimodal network. All the previous representation of this kind where based on terrestrial networks, including road and high speed rail. In this paper we will develop the model in the direction of long distance air mode in the objective of exploring time-distances at the global scale.

2. Air and road modes as inter- and intra-metropolitan major transport systems

Globalisation, considered together with metropolisation as its urban counterpart, is being made possible by the development of efficient, long-haul and short-haul transport systems. If metropolises can be defined as urban entities that communicate at the global scale, the air mode constitutes the prominent passenger transport system associated with globalisation (Sassen 1991; Haggett 2001). Indeed, the equipment of metropolises with airport infrastructure or the number of flights and destinations available are often used as indicators of the position of cities in the global competition (Rozenblat and Cicille 2003; Taylor 2004). Nevertheless, the development of the air mode during the 20th century has not lead to the replacement of other slower transport system; each transport mode has developed inside its

own space of predominance, with fierce competition in the margins. At the scale of metropolitan spaces, the road system can be considered as the major mode, even if regional specificities can be stressed (Kenworthy and Laube 1999). The overall picture of mobility involves two distinct levels with the agglomeration or local level dominated by car and the longer distance dominated by air. This typology has to be put in correspondence with the functioning of urban systems with intra-metropolitan and inter-metropolitan components associated with privileged transport modes. In order to complete the analysis, this picture has to be enriched marginally with the development of other transport systems, urban public transport and high speed rail, each of them operating in complement more than in substitution with respectively cars and planes.

We want to address the question of the time-distances between metropolises. Our model is based on average speeds that determine the time-distances on the map. We proposed to consider the distances in kilometres between city cores as relevant measures of inter-metropolitan trips. From this dataset, the next step is to measure the time spent with the air transport mode in order to produce one or several average speeds. Nevertheless establishing the speed allowed by the air mode constitutes a methodological issue.

We have considered on Figure 3 a sample of inter-metropolitan direct flights inside the USA in 2007. Distance as the crow flies has been considered between urban centres, while the time spent refers exclusively to the commercial schedules proposed by the airlines for direct flights. The figure shows a distribution of speeds ranging between 650 kph to 150 kph that is strongly related to the straight line distance but also depends on other factors.

One the one hand an example of existing short distance inter-metropolitan relation by air is given between New-York and Philadelphia with 65 minutes necessary to link two airports for an intercity distance of 145 km (89 mi).

On the other hand the speed of the relation between New-York and Los Angeles is approaching the cruise speed of typical jet planes around 850 kph.

The explanation of this distribution can be found in several factors. Firstly the schedules provided by airlines include the time spent by planes on the ground before take-off and after landing which does not depend on the overall distance and can be considered as fixed durations that are specific to the air mode. Secondly on shorter distances airlines use specialised planes, sometimes even turboprops, which are characterised by maximum speeds lower than that of planes that one can find on long-haul routes.

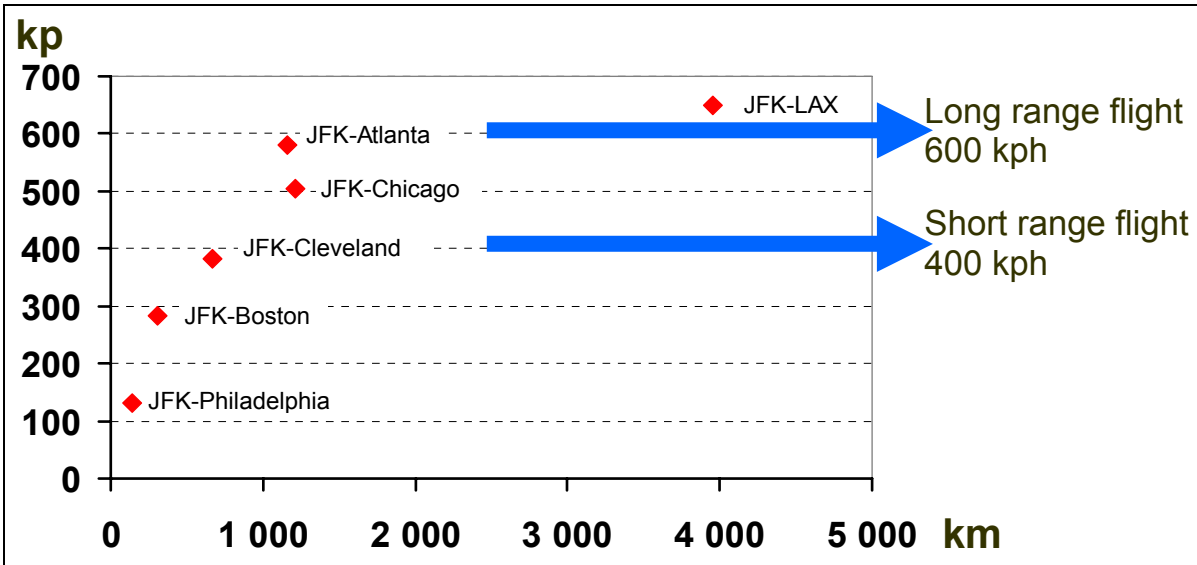

kp
700
600
500
400
300
200
100
0
JFK-LAX
JFK-Atlanta
JFK-Chicago
JFK-Cleveland
JFK-Boston
JFK-Philadelphia
Long range flight
600 kph
Short range flight
400 kph
0
1 000
2 000
3 000
4 000
5 000
km

Figure 3 : time-distances by air between metropolises, the issue of speed

These two elements contribute to the dispersion of speeds in relation to the intercity distance. But another factor has to be discussed in order to complete the analysis. If we consider distances produced by intercity relations the initial and terminal parts of the trips, beyond the airport and inside the metropolitan space, are not included in the dataset. If this element was considered it would even more contribute to widen the gap between the maximum and the minimum speed in the distribution. We can then consider that the present analysis of timetables proposes one step towards a correct understanding of time-distances by air; further developments could be proposed in this direction.
In order to account for this phenomenon of dispersion of speeds we propose to introduce two distinct average speeds, one for long distance close to the maximum, and one for shorter relations. The Figure 3 shows these two measures with 600 kph for long haul and 400 kph for short haul flights.

3. A multimodal model of time-distances

Relief time-distance cartography proposes a relevant representation of distances produced by a multimodal network (L'Hostis 1996; Mathis 1996). In the present application we consider the following couples associating a transport mode and an average speed:

- Long-range air at 600 kph
- Short-range air at 400 kph
- Dual carriageway at 100 kph
- Highway at 70 kph

Two networks allowing four different speeds are used to produce the map. The air network is modelled with two speeds corresponding to long and shorter distance relations, while the speed on the road network is related to the quality of the infrastructure. Most of the inter-metropolitan relations are served by the interstate highway network, and only a few links depend on the use of trunk roads. This differentiation leads to the identification of a network at 100 kph and a network at 70 kph composed of trunk roads.
While on the multimodal terrestrial network of France the differential between the fastest mode with high-speed trains at 220 kph and the slowest modes with the regular road system 60 kph (L'Hostis 2000) was 3.14, the differential reaches the value of 8.5 in the United States time-space. For this reason the image proposed has a much sharper appearance than the previous representations.

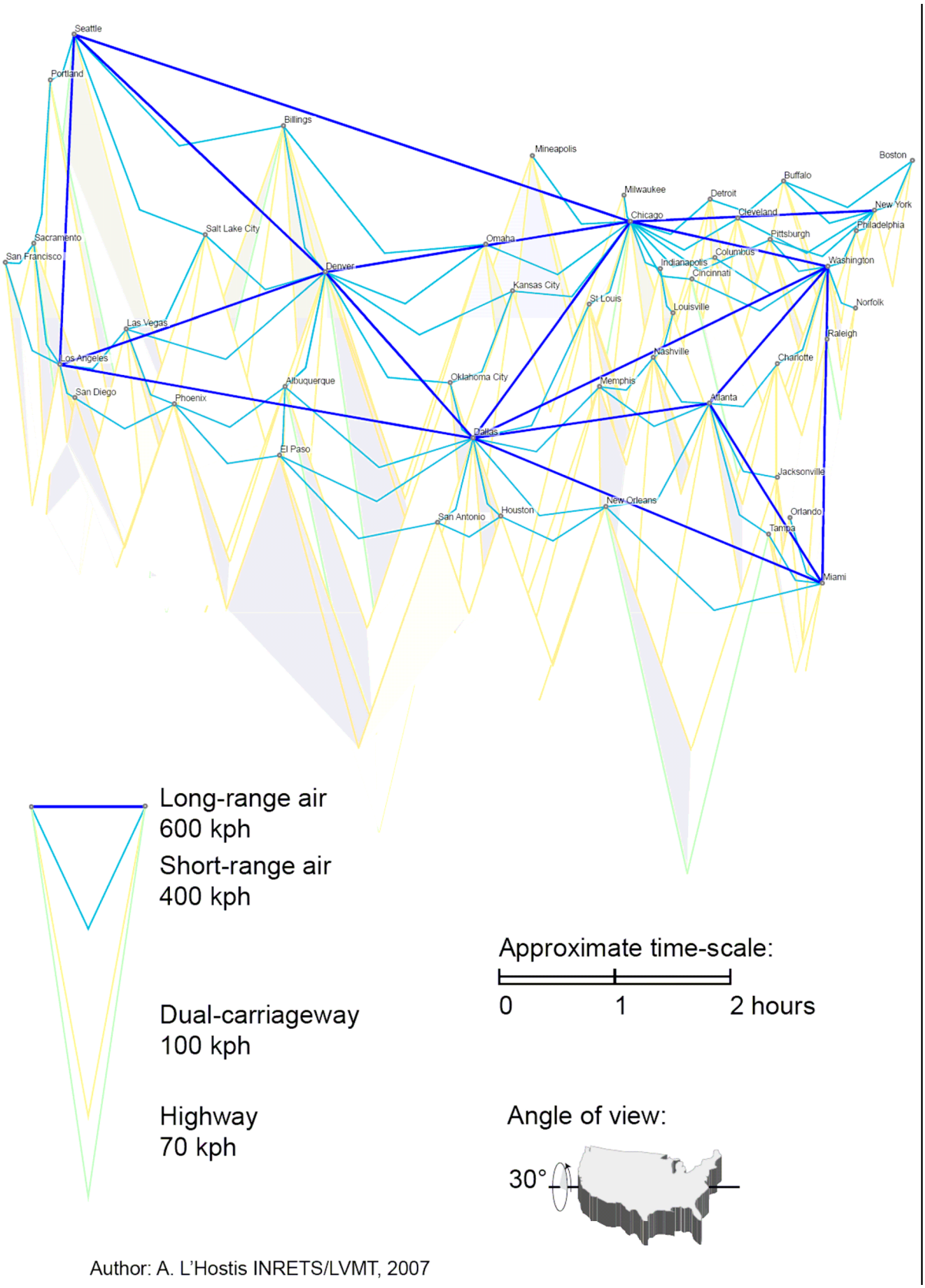


Figure 4: Multimodal "shrivelling" time-space relief map of the USA

The geographical space considered on the map includes the continental part of the USA, Alaska not included. In this space the major cities are included with metropolitan areas of more than 1 million inhabitants. This list is completed with a few particular cities in order to

improve the readability of the cartography. In this perspective, a particular attention is given to the border cities that help to recognise the usual shape of the country, and to the density of nodes. It is the case with Billings (Idaho) counting 150 000 inhabitants and to a lesser extent to Omaha, Albuquerque and El Paso that rank just above one million.
The identification of air links is related to the major passenger air flows existing inside the USA.
The map displays the confrontation between high speeds, accessible through the air transport systems, and the lower speeds of the road network. The angle of view fixed here at 30° permits the reading of the map.
The map expresses the combination of two distinct time-spaces air and road that meet at the location of major urban centres. Metropolises appear as nodes that allow for transfer between fast and slow transport systems between global and local networks. In time-space relief the nodal entities are located at the summit of time-space peaks; this position highlights their role of global/local interfaces. In contrast the rest of space is rejected under the plan of the metropolises. The interstices left between the major urban areas associated to fast-transport nodes forms abysses in time-space reflecting their position of disqualified space when considered in relation with the metropolitan areas.
Let us now go back to the spatial inversion model described by Bunge in Figure 1. In order to adapt the model to the present network characterised by a dramatic development of the air transport we will consider on Figure 4 the space located between the cities of Seattle and Billings in its relation to Chicago. The reader of the time-space relief map can determine a fastest path through the multimodal network. The fact that a shortest path can involve an initial reverse portion of the trip in order to drive to the closest long distance node is clearly expressed by the steep slopes of the road network that contrast with the more “direct” links of the air system. If we adapt the example given by Bunge to the present network, for someone living in the region of Butte in the Montana the choice can consist whether in driving to Seattle to take a direct flight to Chicago or whether driving to Billings and find a connecting flight to Chicago via Denver. In this example the reader of the map can visually add the length of the edges in order to infer a total length that will be proportional to the duration of its trip. This demonstrates that this representation is a time-space map.
Another way to state the property of spatial inversion described by Bunge consists in discussing the idea of “tunnel effect” of fast transport systems mentioned before. The time-space relief map expresses the tunnel effect by representing the fastest links as edges detached from the geographic space and only connected through transport nodes. Tunnel effect refers here to the idea that it is not possible to leave or to access to a fast transport system elsewhere than in the connecting nodes. The effect on space is here a crumpling of interstitial areas while the fast transport entries are getting closer one to another.
The relief time-space map proposes a representation of the spatial inversion where the un-intuitive order of proximities of geographical transport space is made comprehensible.
High speeds reduce time-distances, but high speeds are not available everywhere in space. According to this idea the relief time-space representation shows both short distances between metropolises and long time-distance outside of the high speed network.
Besides these positive elements one must admit that this model of representation suffers from several limitations. Some limitations refer to the way time-distances are considered while others concern the readability of the cartography. Indeed congestion is not taken into account and the connection time between modes or between planes is considered equal to zero. These elements constitute perspectives for the development of the model.
Concerning the readability, the representation poses a new range of problems difficult to tackle. The reader of the map of a country or a continent expects to recognise the overall shape referring to her/his cartographic culture with the north orientation and other

conventional features. By processing string deformation of the conventional map time-space relief representation supposes an effort bythe reader in order understand the cartography. One can assume though that the complicatedness of the representation is in relation with the complicatedness of time-space itself in which spatial inversion perturbs the conventional Euclidean rules. Seen from above the shape of the country is unaltered but then the relief is hardly readable; we have proposed to introduce an angle of view which is relevant to express the shape of the relief without perturbing too much the overall shape. Usually an angle of 30° is used. Nevertheless because of the high differential between speeds, the representation is highly sensible to the modifications of the angle of view. To tackle this issue we have explored three dimensional computer representation and animation techniques that can facilitate the reading of the representation (L'Hostis 2003).
The time-space representation proposes a relevant tool for explaining the functioning of transport systems. It also expresses an image of geographic space that is worth commenting. One the one hand metropolises fostering high-speed nodes occupy the summit of time-space peaks and are closely linked one to each other through the high-speed network. On the other hand the rest of space, the banal non-metropolised space is rejected in time-space valleys and abysses. The overall picture is much in phase with the idea of Graham and Marvin of metropolised space as an 'archipelago of enclaves' that they depict in their book on 'Splintering urbanism' (Graham and Marvin 2001). The representation shows how accessibility between neighbouring metropolises can be of better level than the accessibility between a metropolis and its surrounding space supposed to belong to its area of influence. This image of decoupling of spaces proposes a representation of a key feature of contemporary geography.

4. The 'shrivelling' metaphor

In geography the rhetoric of world contraction can be considered as a fundamental observation with early references of ancient Greeks that perceived the evolution of vessels techniques at the time-scale of the life of a human being and linked it to the reducing of distances between places in the Mediterranean sea (Braudel 1979). In the 19th century already maps of now classical French geography depicted the contraction of the national territory with the improvements of terrestrial transport, while German cartographers mapped the improvement of maritime transport at the scale of the world showing the reduction of travel times at destination and from Europe (Brunet 1987). More recently in the domain of theoretical geography Forer developed the principle of time-space contraction (Forer 1978). Nevertheless critics of the contraction model have been raised noticeably by Kirsch in stating that "space is not "shrinking" but must rather be perpetually recast" (Kirsch 1995). According to Kirsch the evolution of time-space can not be seen as a simple contraction or shrinking process.
The notion of time-space convergence was introduced (Janelle 1968; Janelle and Gillespie 2004) to show that larger cities benefited more than smaller cities from the contraction of time-space by faster transport means. For Janelle the modernisation of transport systems is seen as a factor of concentration in urban agglomerations. In the long time of history the increase of transport speeds has benefited more to larger cities than to smaller settlements. According to Christaller's theory of urban hierarchy large cities are more dispersed in space than smaller ones. Two neighbouring large cities will then be separated by a much longer distance than any two neighbouring smaller cities. Janelle demonstrated that the increase in speed deliver stronger effect on time-space contraction on long distances than on short distance. The evolution of the system of speeds gives an advantage to the larger cities over smaller ones a conclusion which is in line with the literature on metropolisation.

More recently the literature on globalisation (Sassen 1991; Smith and Timberlake 2002; Taylor 2004) takes for base the principle of fast communication and transport at the global scale. Only global transport systems have made possible the present movement of globalisation and the unprecedented concentration of population in major metropolises.
The initial discussion about the three-dimensional model presented here considered the terrestrial relief as the space of reference. The expressions *time-space peaks* and *time-space valleys* referred to the relative position of portions of space in the representation. In the time-space deformation following the introduction in the French national space of the high-speed train system (Mathis, Polombo et al. 1993), the development of new high-speed tangential axis was seen as a way to fill up the valleys dig by the introduction of a differential in transport speeds combined with a star shape of the network (Mathis 1996). This initial works emphasized the analogy with the terrestrial relief.
Later the idea of a time-space 'crumpling' is introduced to develop the metaphor (L'Hostis 2000) on a representation of the European space deformed by the high-speed rail network. The image developed is that of the deformation of a shrivelled sheet of paper, an idea of three dimensional treatment of a plane. The metaphor refers to a shortening of some distances while preserving the initial geographical surface. The metaphor of 'crumpling' opposes the two spaces of high and low speeds and suggests a three dimensional geometric construction coherent with the concept behind the representation. It also proposes a rather negative image with the crumpled surface seen as a degradation of the ideal unaltered flat plane. A positive perspective can be built in considering that the crumpled shape, being more compact than the flat surface, allows for shorter paths between locations. The crumpling metaphor gives an evocative image of the bad treatment reserved to interstitial spaces but is not as expressive of the global contraction of geographical space with the increase in speed.
It is relevant to associate these reflections on the representation of geographic time-space with some recent developments in theoretical physics: the astrophysicist Luminet describes the shape of the universe as crumpled (Luminet 2001) around the idea of multiple folding due to time-space deformation according to the theory of general relativity. Even if establishing relations between completely different fields invites to remain cautious -a use of common words is not sufficient to validate a comparison- it is noticeable that both systems of representation are tightly linked to the identification of a maximum speed. Indeed the light speed is one of the three fundamentals constants in physics. Astrophysicists have to compose with the existence of a maximum speed -light-speed at the scale of the universe- when geographers have to take into account the maximum speed of transport given by the air mode to understand the terrestrial time-space. In order to better understand space both reflections seem to face the need to build complicated representations that divert radically from the common Euclidean geometry.
In the evolution of the discourse produced on time-space relief the following step explore a different type of metaphor based on the idea of *shrivelling*. The first use of the word must be credited to Tobler (Tobler 1999) through his commentary of L'Hostis-Mathis image when he stated that "the world is shrivelling as it shrinks". We move here from an image of shaping an inanimate entity, an artefact, *crumpling a sheet of paper*, to a principle of natural evolution of a living organism *the shrivelling of a fruit*. The shrivelling expresses an idea of contraction with deformation of the envelope: the volume decreases while the external envelope keeps its initial surface.
The strength of the metaphor lies in the combination and the linking of two complementary movements of contraction and deformation of the surface. It is the reduction of the volume due to a loss of substance that provokes the deformation of the skin of the fruit. In Geographic terms it is then possible to explain the tormented shape of the map by the global contraction due to high speeds. The model generates forces of contraction along air routes that apply on

high speed nodes, i.e. metropolises. High speeds and metropolisation make the world shrivelling as it shrinks would then be a reformulation of Tobler's statement.
It is this reflection on the shape of the earth and not only on the shape of a single country or a continent that lead to the necessity of introducing the air mode in the relief representation. Being the global transport mode of reference, the air mode had to be considered: we developed in this paper a proposal for representing global distances and local distances simultaneously. To that extent, the present application on the USA paves the way to a representation of the earth.
From the distribution of world cities and from the description of major air routes and of the intercity terrestrial networks it would be possible to build a representation of the global time-space. The world would then be seen as a shrivelled fruit. If we follow the metaphor of shrivelling we could consider this evolution as a maturing process. We know that the passion fruit is mature and ready to be eaten when it has shrivelled and its skin has crumpled.
But according to the previous discussion on the differential between global speed and terrestrial speed, the intensity of the shrivelling movement will be much more intense for the global space than for the maturing passion fruit. The sharpness of the time-space peaks bearing the world metropolises will produce an image evocating much less the passion fruit than the chestnut. The metaphor of maturing will have to give place to another figure to render justice to the dichotomy of spaces opposing world cities to the rest.

5. Conclusion and perspectives

The time-space relief map shows the complicated phenomenon of contraction and dilatation of space time due to the coexistence of transport networks with different performances. The entry points to the fast transport systems are getting closer from each other meanwhile the interstitial space is rejected in the third dimension.
The time-space relief map is a solution for the representation of distances through the transport networks – where the straight line in the plane is not the shortest path – a question of major importance in geography.
In addition the model proposes a rich interpretation in terms of metropolisation and globalisation processes. Because it is build from the distribution of metropolises and from the shape of the transport network the shrivelled map constitutes a conceptually relevant representation from a geographic perspective. The image produced opposes the upper level urban network with metropolises occupying the summit of time-space peaks tightly related one to another and the rest of the geographic space relegated and rejected in time-space valleys and abysses.

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Early versions of the paper and of the maps have received useful comments from Waldo Tobler. The author thanks him for this.
The language barrier prevented the author to fully understand Tobler's statement that "the world is shrivelling as it shrinks" until a particular morning of the winter 2005 when Jules the 8 years old son of the author used the word 'crumpled' to describe the shape of a passion fruit he intended to eat. Thanks to Jules.

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