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Comparative Analysis of Regional Development: Exploratory Space-Time Data Analysis and Open Source Implementation

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Abstract
This paper aims to make contributions to comparative analysis of regional economic dynamics in China and the US from the methodological perspective. More specifically, some recent advances in exploratory space-time data analysis (ESTDA) will be suggested and implemented to conduct this task in an open source environment. China and the US have been the subject of much discussion about the patterns and trends of regional development, because of their importance in the world economic system. Despite the rich and growing empirical literature on numerous case studies at both national and sub-national scales, comparative space time analysis between and within these two economic systems has just begun to catch attentions. Additionally, ESTDA and its open source implementation can facilitate comparative studies of regional development.

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Keywords ETSDA; regional development; comparative analysis; open source; China; USA

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1 Introduction

GIS and regional economics have been, and continue to be challenged by dealing with temporal trend of geographic patterns and spatial dynamics of economic development (Goodchild, 2008; Rey, 2009; Anselin, 2010). There is an imperative need for effective and efficient methods to represent and examine the coupled space-time attributes of economic phenomena in the comparative context (Janikas, 2007; Goodchild and Glennon, 2008). The growth in international trade, the restructuring of economies under reform, and widening regional inequality, have reemphasized the importance of geographical analysis. Theory, methodology, and practice of temporal GIS has emerged as an active domain to address these challenges while a large amount of efforts are still needed in integrating regional economics with temporal GIS (Ye and Rey, 2011). As a multi-dimensional and multi-scale phenomenon, regional development witnesses the role of geography and the awakening emphasis on space among economists. Additionally, it is more interesting to what extent that geography matters, which is also stimulated by the emergence of new economic geography (Krugman, 1999; Fingleton, 2004; Anselin, 2010). This paper suggests some novel exploratory approaches to compare spatial pattern and temporal trend of regional development between China and the US. Accordingly, a reasonable number of research hypotheses can be developed. The cross-fertilization between ESTDA (exploratory spatial data analysis) and regional studies is thus identified and illustrated.

As Rey and Ye (2010) argue, “in order to develop a more spatially explicit growth theory it is first necessary to develop operational measures that capture the spatial dynamics inherent in regional datasets”. Hence, this research aims to provide new insights on comparative regional studies by revealing and quantifying the changes and level of hidden variation across scales and dimensions. More specifically, the paper reveals the comparative spatial dynamics that underlie regional development by visualizing the similarity of time series across various intervals and interactively investigating the growth trajectories of states and provinces using comparative LISA (Local Indicators of Spatial Association) time path, in order to shed light on the debates on mixed conclusions derived in many case studies. The above new advances are developed in an open source environment, which offers a straightforward way of benefiting wider community. As such, explanations of various regional development styles can be provided based on rigorous analysis, and policy interventions are then proposed in light of the understanding of the space-time data set.

This paper is organized as follows. The next section presents a literature review of ESTDA and open source spatial analysis, along with the competing interpretation of regional economic dynamics between and within China and the US. This is followed by an illustration of some recent development of ESTDA in an open source environment, using the GDP per capita data in China and the US over the 1978–2008 period. This paper closes with some final points. The purpose of this paper is to promote and realize an open source implementation to conduct comparative exploratory space-time analysis of regional economic data, which is viewed as an initial step towards the goal of exploring and sharing development opportunities between and within China and the US.

2 Literature Review

China’s mounting importance in the world economic system since the launch of reforms in the late 1970s has long been the subject of intense academic debates, in terms of its spectacular growth and poverty reduction. After overtaking Japan as the world’s secondary largest economy, China is now challenging the hegemonic status of the US. As Wei (2006) comments, “the rise of China and its challenge to US hegemony is a hot topic in the media and popular magazines such as Foreign Policy”. Such phenomenal development has been a hallmark of China's growth, and has been gaining attentions and recognition (Fan and Sun, 2008). The speed and unevenness of economic restructuring and development in favor of specific regions, is truly unprecedented and merits a careful examination and assessment both theoretically and methodologically. Scholars have been intensely debating the impacts of the reform on regional convergence and inequality (Weng 1998; Wei 1999; Li and Haynes, 2010). Research has revealed that patterns of regional inequality differ with geographical scales, thus creating a multiscalar typology of regional inequality in China (Wei and Ye, 2009). Multi-scale and multi-mechanism approach has been adopted, with a synthesis of global, state and local forces in understanding the process of regional development (Yu and Wei 2003; Ye & Wei, 2005; Li and Wei, 2011).

Many studies on US regional income growth patterns have been conducted from the perspective of either geographical dynamics or time series (Fan and Casetti, 1994; Rey and Montouri, 1999; Tomljanovich and Vogelsang, 2002; Rey 2004a, 2004b; Sommeiller, 2007). Fan and Casetti (1994) argue that the inverted-U hypothesis cannot explain the rich details of regional dynamics and conventional approach of measuring systemic inequality conflates the large regional variations. Rey and Montouri (1999) examine US regional convergence from a spatial econometric perspective, finding that the level of global spatial autocorrelation temporally associates with regional income dispersion. Tomljanovich and Vogelsang (2002) detect strong evidence for regional convergence based on time series methods. Rey (2004a, 2004b) develops a series of spatially explicit methods of data analysis to address the geographical and distributional dimensions of regional convergence and inequality. However, the findings are mixed, ambiguous, and sometimes conflicting due to different research design and analytical strategies. Sommeiller (2007) states that "the neoclassical economists support convergence whereas the geographers marshal evidence for divergence, at least in the case of the United States at the sub-national level".

Not surprisingly, growing inequality across various spatial scales threatens the social harmony and thus erodes the political basis for economic growth in both China and the US. This concern is exemplified by Levy and Chowdhury (1995)'s comment that "large income and wealth differences between countries and regions generated acts of aggression which inflicted considerable human suffering, loss of resources and knowledge, destruction of civilizations and environmental damage." Meanwhile, a number of fascinating debates on the trajectories and mechanisms of regional development are reflected in numerous empirical studies of specific regions in these two countries. Despite this rich and growing list of empirical literature, comparative analysis of regional development between and within China and the US remains largely unexplored. It is fascinating to detect a daunting list of differences and similarities between and within multiple regional systems. Researchers and policy makers can gain better understanding of different economic development mechanisms and policy implementation schemes based on comparative analysis (Ye and Rey, 2011).

The region serves as a useful unit of observation to test competing economic growth theories and regional economic hypothesis (Quigley, 2001). Abundant evidence has exhibited that spatial variation of regional development fails to be predicted or explained (Rey and Montouri, 1999; Anselin, 2010). Though rich conceptual frameworks have highlighted the spatial dynamics and unevenness of income distribution processes, many implementations of growth theories in estimable econometric specifications do not appropriately treat dynamic spatial effects in the data (Rey and Janikas, 2005). A key issue is that the interaction between regional economics and space time analysis has not been as strong as perhaps it could be. Fundamentally, the most crucial step is to systematically understand the data before testing hypotheses. Researchers have to get acquainted with the data before formulating meaningful research questions or carrying out action plan.

"Getting acquainted with data" is the task of exploratory data analysis (EDA) (Andrienko and Andrienko, 2006; Anselin, et al. 2006). The debates on regional convergence and inequality dynamics have been informed by, and to some extent inspired by, a parallel development of new space-time methods which has quantified the magnitude of regional dynamics (Miller and Wentz, 2003; Getis et al., 2004). The space-time perspective has become increasingly relevant to the understanding of economic development and novel methods are needed to truly integrate space and time (Ye and Carroll, 2011). A number of EDA techniques have been applied to the dynamics of regional income distributions. Indeed, EDA is to analyze data for the purpose of interactively formulating hypotheses instead of testing hypotheses (Andrienko and Andrienko, 2006; Guo and Mennis, 2009). Moreover, EDA can reveal complex space-time economic phenomenon not identified otherwise (Le Gallo and Ertur, 2003). Rey and Ye (2010) argue that space-time methods can be generated by either incorporating spatial dependence into the time series or extending static spatial associations to a temporal context.

During the past several decades, a number of efforts have been witnessed on the development and implementation of spatial statistical analysis packages, which continues to be an active area of research. Familiar reviews of these issues are represented in, among others, Anselin and Getis (1992); Getis et al. (2004); Rey and Anselin (2006); Anselin (2010). This is exemplified by the growing software list with a quite considerable collection which is maintained by Center for Spatially Integrated Social Science (CSISS). The history of open source movement is much younger, but its impact on GIS world is impressive (Rey, 2009). Open source, therefore, represents a paradigm shift in geospatial research that has facilitated collaboration across disciplines. According to Lewis (2011), about 300 Open Source / Free GIS related software projects are created after 15 years of open source movement. As Rey (2009) comments, “a tenet of the free software (open source) movement is that because source code is fundamental to the development of the field of computer science, having freely available source code is a necessity for the innovation and progress of the field”. This user-led innovation in the open source movement is also the philosophy of conducting research in regional economic geography. The development of open source GIS packages has been boosted. However, open source projects in the areas of advanced spatial analysis are very few (Rey and Anselin, 2007; Rey, 2009).

3 Comparative Analysis

Exploratory data analysis has a significant appeal for comparative analysis because it can help generates a comprehensive list of novel hypothesis. During the course of analysis, as something interesting to researchers is detected in the data, new research questions arise, causing specific regions or relationships to be scrutinized in more detail. In the rest of this section, some methods are highlighted drawing on examples from per capita GDP distributions of China and the United States from 1978 to 2008. The recent interest on comparative spatial economic dynamics centers on two main dimensions of regional evolutions. The first concerns how similar/dissimilar time series distribute over space. The second dimension relates to the temporal trend of spatial pattern. Rey and Ye (2010) suggests spatial network/spider graph and LISA time path to address these two concerns. Some initial designs of these geo-visual analytical methods are available in the package STARS (Space-Time Analysis of Regional Systems) (Rey & Janikas 2006). As an open source toolbox designed for the analysis of space-time data, STARS is featured with an array of dynamically linked graphical views. Written entirely in a scripting language Python, STARS can be easily expanded to support more flexible and specific types of analyses. As such, the current research extends these two general notions into a more interactive and comprehensive context.

In the following sections, comparative space-time analysis of regional systems will be conducted using case studies of China and the US. The two data sets are relative per capita gross domestic product (GDP) over the 1978-2008 period at the province and state (contiguous United States) levels. These two data sets are comparable because the states (contiguous United States) and provinces (China) are self-contained and well-functioning units which form the theoretical structure for spatial interaction models in spatial economy (Fan and Casetti, 1994; Fan and Sun, 2008).

3.1. Comparative Network and Spider

The network approach visualizes the covariance matrix of regional growth on a single map. Figure 1 is generated using the package STARS. The temporal correlation matrix is a matrix of correlation coefficients between the time series of per capita GDP of each state (province). Through integrating a spatial component, the time series can be represented geographically using the network approach. More specifically, this pairwise approach provides a measure of the strength of the correlation between two sets of incomes in the spatial setting.

Links connecting the centroid of each region (polygon) are defined by spatial weights matrix, which decide whether any pair of observations are neighbor. In Figure 1, first order contiguity is employed as the default option, but other types of spatial weight matrix can also be used to define the neighboring spatial units of a focal observation. In other words, researchers have the flexibility to define which observations are neighbors to a focal observation based on the conceptual framework.

In the current design of STARS, the color of the links on the map are conditioned on the strength of the temporal covariance between each pair of neighboring regions, with the red segment indicating an below-average correlation (weak temporal linkage) while the blue one suggesting an above-average correlation (strong temporal linkage). Two neighboring provinces connected by blue links are considered to be similar in the temporal dynamics since the correlation of their income time series is above the national average. This closeness can be interpreted that the two involved economies share some similar economic development mechanisms, or interaction might exist between them. If a region has strong temporal linkages with all of its spatial neighbors, there might be strong space-time economic integration for the focal economy.

(Figure 1 about here)

However, the above visualization masks two important issues. First, positive correlation and negative correlation are mixed. Second, the spatial distribution of correlation coefficients are oversimplified by the classification based on the cutting point of the average. Limiting attention to either magnitude or sign of correlation coefficients may result in a misguided or partial understanding of regional dynamics. As Rey and Janikas (2006) state, "explore patterns through various interfaces and the views are dynamically integrated with one another, giving rise to the second meaning of dynamic spatial data analysis (the first meaning is incorporating time to spatial data analysis).” The details of temporal linkages for each possible region-pair can be further interactively visualized.

It is not surprising that similar time series tend to geographically cluster, as shown in Figure 1. However, it is more interesting to see how the spatial pattern of links changes according to the varying size and direction of correlation coefficients. Figures 2, 3, and 4 thus visualize how neighboring economies relate to each other over time in these two regards. Ignoring the rich details of these relationships leads to overlooking many possible interactions and dependence among regions. Figures 2, 3, and 4 extend the previous work of STARS by distinguishing the direction and size of correlation coefficients in an interactive manner, which in turn generate different perspectives of looking at the same time series data. In other words, it is valuable to consider all possible spatial perspectives before formulating research questions.

(Figure 2 about here)

In Figures 2, 3, and 4, solid blue segments indicate positive temporal linkages while dotted red segments signify negative temporal linkages. More specifically, this extended network graph identifies both similar and dissimilar economic growth trends quantitatively (the absolute value of the correlation coefficient) and qualitatively (the sign of the value). As such, various levels of correlation can be visualized, and this will more distinctly identify cross-sectional relationships. The relationships between a focal economy and any of its neighboring economies are divided into multiple groups based on user’s input. For instance, the left graphs on Figure 2 display the distribution of direction of correlation since the threshold of absolute correlation value is set to be zero. The China case shows that most of the negative correlation links exist between coastal provinces and their immediate inland provinces, while all the neighboring inland provinces and coastal provinces have positive correlation coefficients among themselves. This further justifies the widening and consistent inequality between coastal and inland China (Wei and Ye, 2009). At the same time, it also vividly shows the spatial footprint of coast-oriented regional development policy, because the coastal provinces are sharply separated from inland provinces. When only the absolute correlation values above 0.5 are allowed to be drawn (the top right graph in Figure 2), most of the disappearing links are located between central provinces and their immediate neighboring coastal and other inland/western provinces. This disconnection, instead of dissimilarity, also proves the widening coast-inland inequality. The US case demonstrates an obvious northwest-southeast corridor of negative links (the bottom left graph in Figure 2), while the threshold value of 0.5 further identify several regional economic groups, such as economically-integrated Northeastern US and diverse Western US. Florida, a coastal state largely based on tourism and elderly residents, is isolated from its neighboring states, part of a large cluster of poverty trap.

Figure 3 and Figure 4 list the snapshots of the maps based on inputs of 0.2, 0.4, 0.6, and 0.8. It should be noted that any value can be selected by the sliding bar, and the corresponding network map can be immediately drawn. Figure 3 and Figure 4 show that when the absolute value of correlation coefficient increases, majority of segments left on the map are solid blue in both countries. Larger values in correlation mainly indicate similarity of growth prevail among neighboring province or states. However, it is worth noticing that only two strong negative links (<= -.0.8) exist in China, and both of them connect to Guandong, a province on the South China Sea coast. Meanwhile, no strong negative links are identified in the US.

Two robust phenomena survive the changing correlation value thresholds. First, there is a ‘rectangular-size’ cluster of strong segments in southwestern China, where a poor trap has formed over years, while at the same time period there is a liner-shape of wealthy provinces with similar time series displayed along the coast. Second, there are two persistent regional clusters in the US: the Northeast-Mid Atlantic cluster of high income states and deep Southeast cluster of low income states.

(Figure 3 about here)

(Figure 4 about here)

A spider graph reflects the correlation of incomes between a province/state and any of the rest provinces (states) (Figure 5) (Rey and Janikas, 2006). This graph relaxes the contiguity constraints in Figure 1, and visualizes the time series correlation between a specific region and any of the rest of the regional system. Hence, the spider graph reveals the possible economic integration of each focal region with their respective national system. As such, this method aims to identify the specific regions with which they share common dynamics, as reflected in above-average standardized pairwise correlations in economic dynamics. These are indicated by edges connecting each focal region to the dynamically similar regions. This is illustrated in the spider graphs of two regions by STARS: Guangdong in China and Florida in the US. Guangdong is in sync with coastal provinces while all of Florida's similar sets of linked states do not locate in any neighboring spatial units (Figure 5). However, this map also masks the details as Figure 1 does. In other words, this macro division can frequently mask a great deal of turbulence at finer scales.

Figure 6 extends the new design in Figure 2 to the case of spider graph. When the threshold values change from 0.2 to 0.8 using 0.2 as the step length, Guandong's positive links display a higher degree of stability with six coastal provinces staying through 0.6 (Hainan leaves the list when 0.8 applies). This is complicated by the radically different levels of negative links over time (22, 19, 14, and 10). At the same time, a casual inspection suggests that Florida has relatively changeable lists of both positive and negative links. When the threshold is set to be 0.8, only one positive link (California) and two negative links (Nebraska and Kentucky) remain. Hence, researchers can further identify which provinces or states might have very different economic development paths from the rest economic units, as well as the extent to which the difference is.

(Figure 5 about here)

(Figure 6 about here)

(Figure 7 about here)

3.2 Comparative LISA Time-Path

LISA (local indicator of spatial association) is an indicator to examine local spatial dependence (Anselin, 1995). LISA Time Path extends this static spatial statistics to a temporal setting by plotting the pair-wise movement of a given variable of the focal unit (X coordinate) and its spatial lag (Y coordinate) over time (Rey et al., 2005). At a given time, each region can be identified with these X and Y coordinates. Hence, each region has a directional path connecting all the coordinates by temporal order. Figure 8 illustrates the co-movement of a region's GDP per capita and its spatial lag over time in STARS, which can be used to identify levels of stability of a region with a given structural process (the x-axis refers to a province/state's per capita GDP relative to the national average, and the y-axis refers to its spatial lag). A variety of geometric properties can be summarized for each region's LISA time path, since individual aspects of the same contemporaneous process can be dissected by interval gaps. When viewed in a comparative context, the geometry of the paths (the trajectory of LISA of specific economies) can illuminate aspects of various regional growth processes.

(Figure 8 about here)

(Figure 9 about here)

(Figure 10 about here)

As Figure 8 illustrates, Guandong (top) and Florida (bottom) have been witnessing sharply different trends of relationships in their local linkages. However, this visualization can be further improved if any selected regions can be visualized on one map (under the same scale) with the arrow of path indicating the direction. Figure 9 thus compares Guandong and Florida under the same scale. Some interesting phenomena are detected. First, the distinct performance of the two coastal regions reemphasizes the importance of location factors in the economic landscape. Compared to Guandong, Florida has a very torturous path in a much smaller activity space on the Figure, while it depicts a relatively sharper decline and rise on the neighbor side. Over 21 years, the range on the X axis is 0.747 for Guandong (0.042 for Florida) and the range on the Y axis is 0.082 for Guandong (0.005 for Florida). The national status of GDP per capita of Guandong's neighbors is much lower than Florida's, and both of them are below the national average in China and the US. Guandong's average neighbor increases from 0.585 in 1978 to 0.667 in 2008, while Florida's moves slightly from 0.828 to 0.883 during the same time period. The striking feature is Guandong's rocketing economic status. Guandong used to be lower than that of Florida in the US, but it dramatically increased from below the national average to one of the richest provinces (comparing the X axis). Guandong moves from 0.785 in 1978 to 1.532 in 2008, while Florida drops from 0.907 to 0.865 during the same time period. In other words, Guandong makes a dramatic transition from 21.5 percent below the national mean to 53.2 percent above the national average. Second, Guandong's LISA Time Path has contained most of the big jumps in status move-up and move-down, which take place when the segments lean towards the X axis. This phenomenon means the role of Guandong is decisive in its local regime.

However, Florida demonstrates an opposite trend, which indicates that Florida is overwhelmed by its neighboring states in development.

Figure 10 further demonstrates how this new method can be used to compare the evolution of local economic regime in each country, by contrasting the LISA time paths of various regions at the same scale. Guandong and Fujian have been identified to have strong positive links in the spider figure, and their LISA time paths are compared on the top graph of Figure 10. Since Florida and California have strongly-correlated time series, their LISA time paths are also compared. Guandong grows much faster than Fujian (Guandong increases from 0.785 to 1.532, while Fujian is from 0.581 to 1.056), while the latter's neighbors benefit more than the former's (Guandong's Y value move from 0.585 to 0.667, and Fujian's increases from 0.692 to 1.192), which further validates the persistent poverty of Guandong's neighbors at this finer scale. A U shape (California) and an inverted U shape (Florida) with many short-lived phenomena of status change are identified on the bottom graph of Figure 10. California (Florida) and its average neighbor change from 1.127 (0.907) and 1.058 (0.828) to 1.105 (0.865) and 0.971 (0.833) respectively. The network graph, in conjunction with the spider figure in the previous section highlight that California and Florida are largely isolated from their neighboring states due to the low correlation coefficients, which can be partly explained by the existence of many path segments parallel to either X or Y axis. These segments dramatically decrease the relevance of the two states to their neighbors in the statistical results. Hence, the comparison of LISA Time-Paths can reveal important insights as to regional income disparities. Additionally, a closer inspection reveals that China has much more dispersed spatial dynamics in Figure 9 and Figure 10, which indicate the possible existence and practice of a variety of economic development models, as well as a large and persistent inequality in China due to both economic success and problematic development (Fan and Sun, 2008; Wei and Ye, 2009). The peaks and troughs shown in Figure 9 and Figure 10 also imply that the economic reform policy starting from 1978 are vital to explain changes in regional growth and inequality.

The relative levels and pace of change of a region can thus be investigated and compared at the individual scale. That is, a particular region's economic status fluctuates, or moves up/down relative to the national average. At the local scale, a focal economy might have a different velocity of development rate from its neighboring ones over time. This comparison provides important insights to the finer-scale aspects of stability and distinct directional movement within various dynamic regional income distributions, because the convergence hypothesis is concerned with these distributions over time.

5 Summary

Spatial turn in many socioeconomic theories has been noted in a vast field, encompassing both social and physical phenomena (Krugman, 1999; Goodchild, 2008; Sui, 2011). This intellectual and technological change has yielded important insights on physical sciences, social sciences and the humanities, with an explosion of interest across disciplines (Peuquet, 2002; Batty, 2005; Sui, 2011). Regional variations in economic development are highly topical subjects for intellectual enquiry and have long been the focus of policy initiatives. The empirical observations in the current research lend support to the notion that the multi-scale and multi-dimension methods can expose some hidden space-time patterns and trends that otherwise would be very difficult to detect in regional economic studies.

Bode and Rey (2006) call for "further research on integrating space into formal theoretical models of growth and convergence as well as on developing the next generation of analytical methods needed to implement those models" as "the preconditions for reliable policy recommendations, one of the primary goals of economic research". The fast growth in spatial economic analysis is increasingly seen as attributable to the availability of panel regional economic datasets. By contrast, regional geographers have been slower to adopt and implement new spatially explicit methods of data analysis due to the lack of extensible software packages, which becomes a major impediment to promote spatial thinking in regional geography studies.

Meanwhile, spatial economic analysis is increasingly being supported by the emergence of advanced analytical methods in space-time data analysis and data visualization. The interactive spatial data analysis has motivated, if not directly provoked, new queries on spatial economic theories. Therefore, the current research implements the new methodological advances in an open source environment for exploring data that has both temporal and spatial dimensions, which lend support to the notion that space and time cannot be meaningfully separated. This paper thus demonstrates an example to interface academic spatial analysis with the open source revolution, which is among the burgeoning efforts seeking the cross-fertilization between the two fast-growing communities (Rey, 2009). The research provides an extension of some current functions in the open source package STARS with an eye towards promoting comparative space time analysis of regional systems. As Rey (2009) suggests, "increased adoption of open source practices in spatial analysis can enhance the development of the next generation of tools and the wider practice of scientific research and education". As such, this paper helps to speed that adoption by investigating the role of space and scale in the comparative analysis of regional income inequality in China and the US over the 1978-2008 period. The concept of exploratory space-time data analysis is strongly associated with visualization because graphical presentation enables the analyst to open-mindedly explore the structure of the data set and gain some new insights, as illustrated by the comparative network/spider figures and LISA time paths. Shneiderman (1996) argues that exploratory data analysis can be generalized as a three-step process: “overview first, zoom and filter and then details-on-demand”. More importantly, it is worth noticing that this process should be iterative, and the methods implemented in the current research addressed the challenge. To explain the observed patterns and trends, a follow-up research is needed on collecting determinants of economic growth.

This open source work procedure can facilitate the interdisciplinary research due to “the collaborative norms involving positive spillover effects in building a community of scholars” (Rey, 2009). The package of STARS is entirely open source, which can promote collaboration among researchers who want to improve current functions or add extensions to address specific research questions in regional studies.

Based on the strength of scientific visualization techniques, this paper stresses the need to study the space-time dimension underlying regional economic data sets. This work provides insights as to the possible spatial pattern of the selected correlation coefficients over time, temporal dynamics of associated regions, and economic growth of a specific region. Finally, a new interactive tool is suggested and demonstrated as providing an explanatory framework for space-time economic data. On this basis, the sincere hope here is that this dialogue between regional economics and ESTDA will embrace the real world challenges of economic inequality issues.

ESDA is not new to economic convergence and inequality studies, whereas extending ESDA into a dynamic context, no doubt, would give better support for the scientific investigation and management of regional economic data sets, including its description, representation, analysis, visualization, and simulation. Additionally, comparative space-time analysis enables access to a much wider thinking which addresses the role of space at different stages of economic growth and thus identifies the research gaps and opportunities for more in-depth study. This paper explores the potential for the new methods to function in regional studies, specifically, in the comparison of income distribution dynamics between different economic systems. In other words, the current work is mainly from an exploratory perspective, which can motivate regional and economic geographers to design a series of regional economic analysis questions and formulate new hypotheses from theoretical and policy perspectives. This space-time work provides an important contribution to the current economic convergence and inequality literature, which lacks in comparative space-time studies. Although this comparative study arose in the analysis of income distribution dynamics, it broadly aims to analyze the role of geography and location in socioeconomic phenomena. Hence, it can also be applied to a wide set of socioeconomic processes with geo-referenced data measured over areal units at multiple time periods. In addition, the methods are built in open source environments and thus easily extensible and customizable.

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Figures:

Note: cnpcr indicates per capita income relative to the national mean in China; uspcr indicates per capita income relative to the national mean in the USA. These abbreviations apply to all other figures.

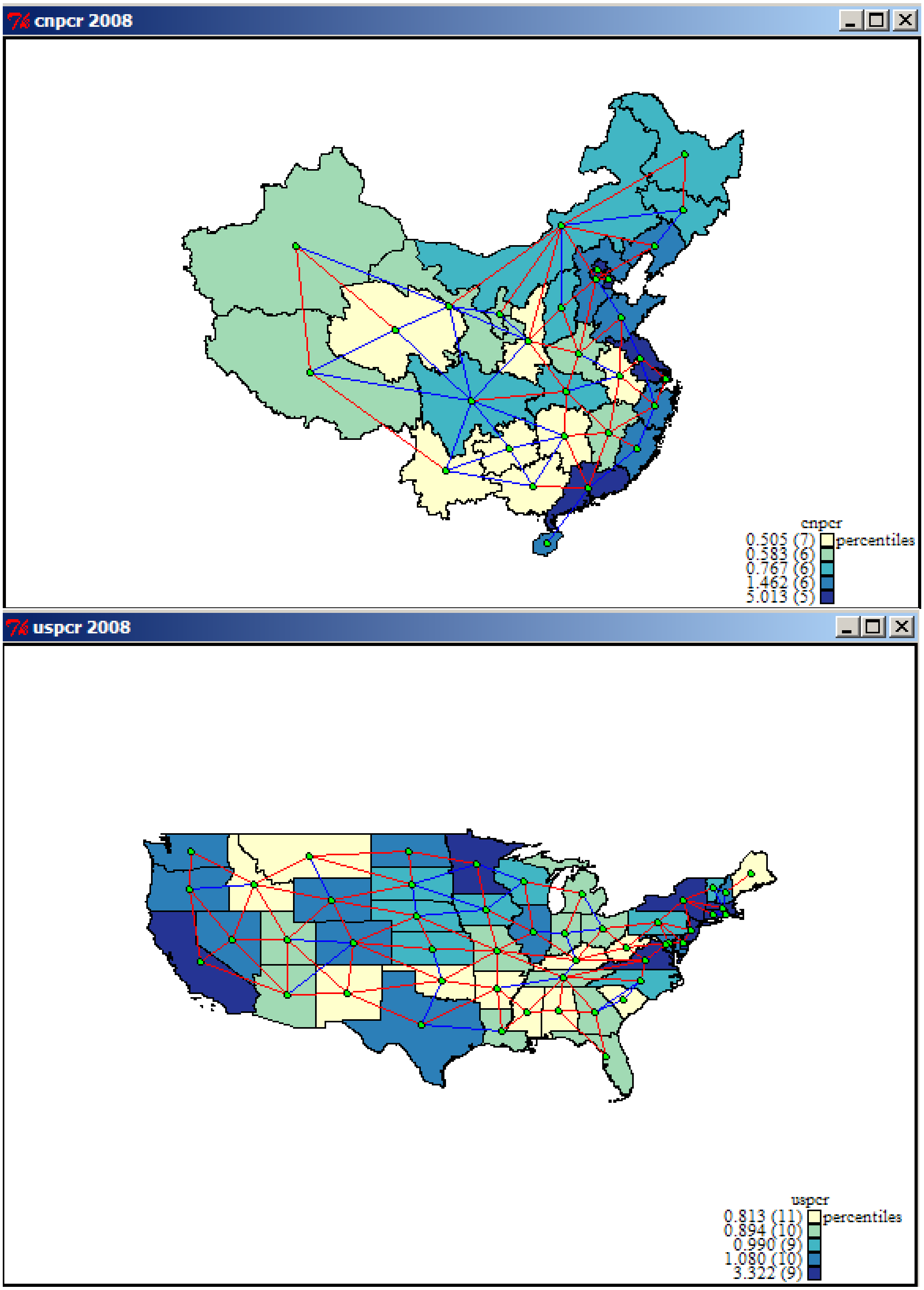


Figure 1 Spatial Correlation Network in China and the US Generated by STARS

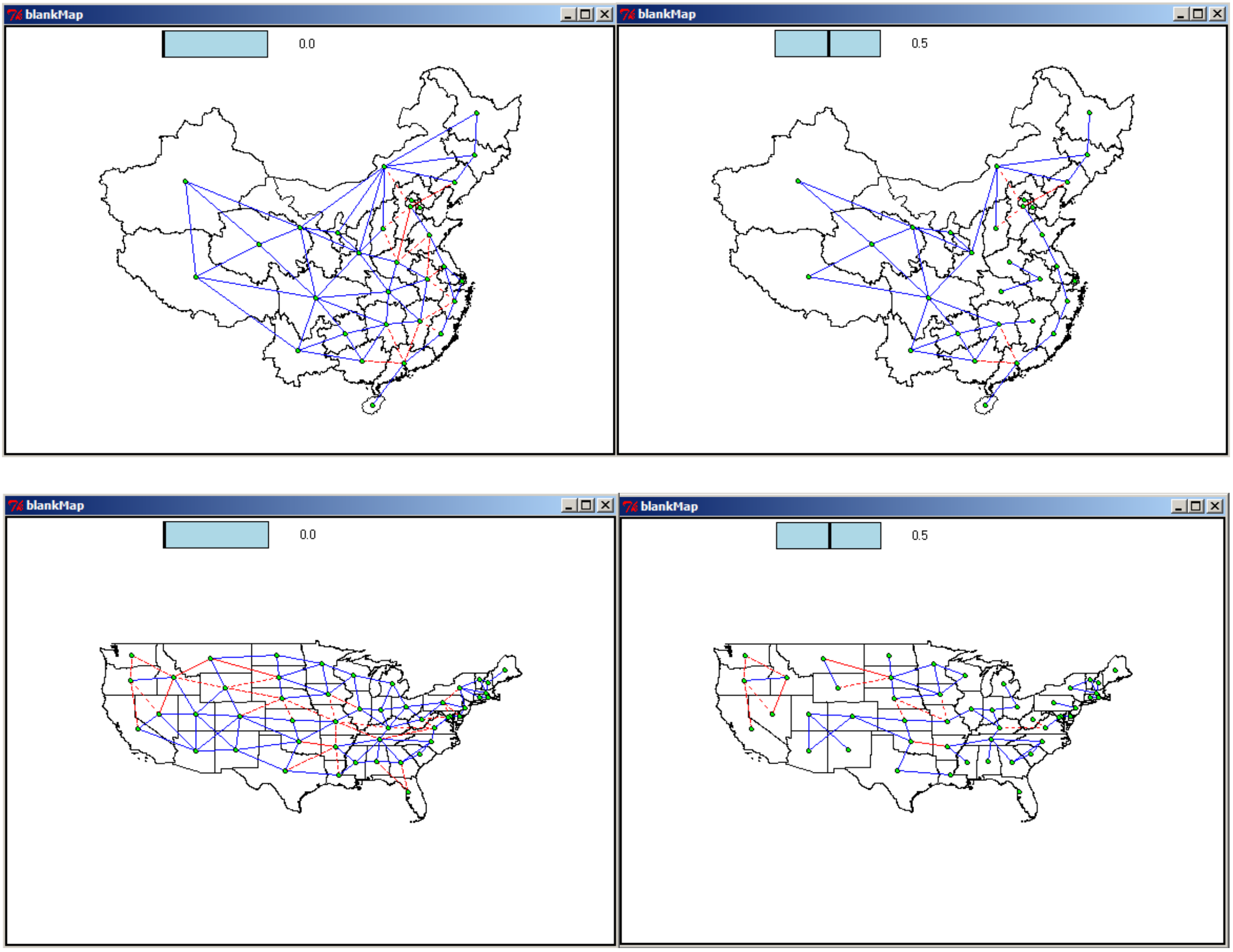
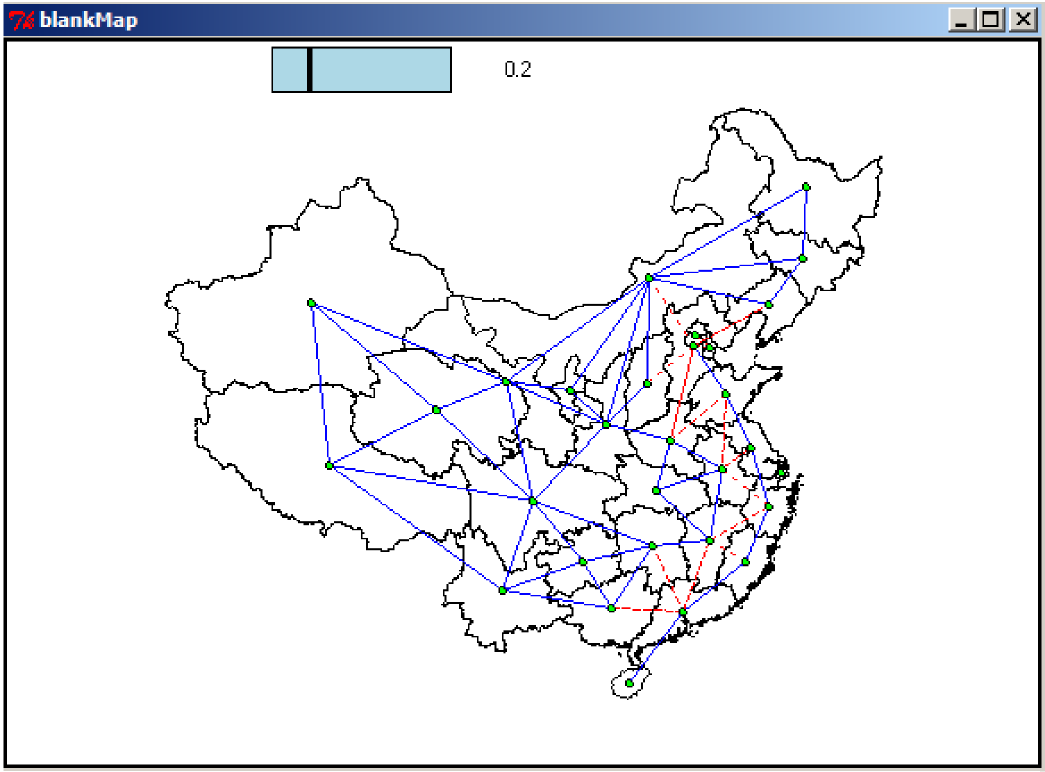


Figure 2 New Design of Spatial Correlation Network in China and the US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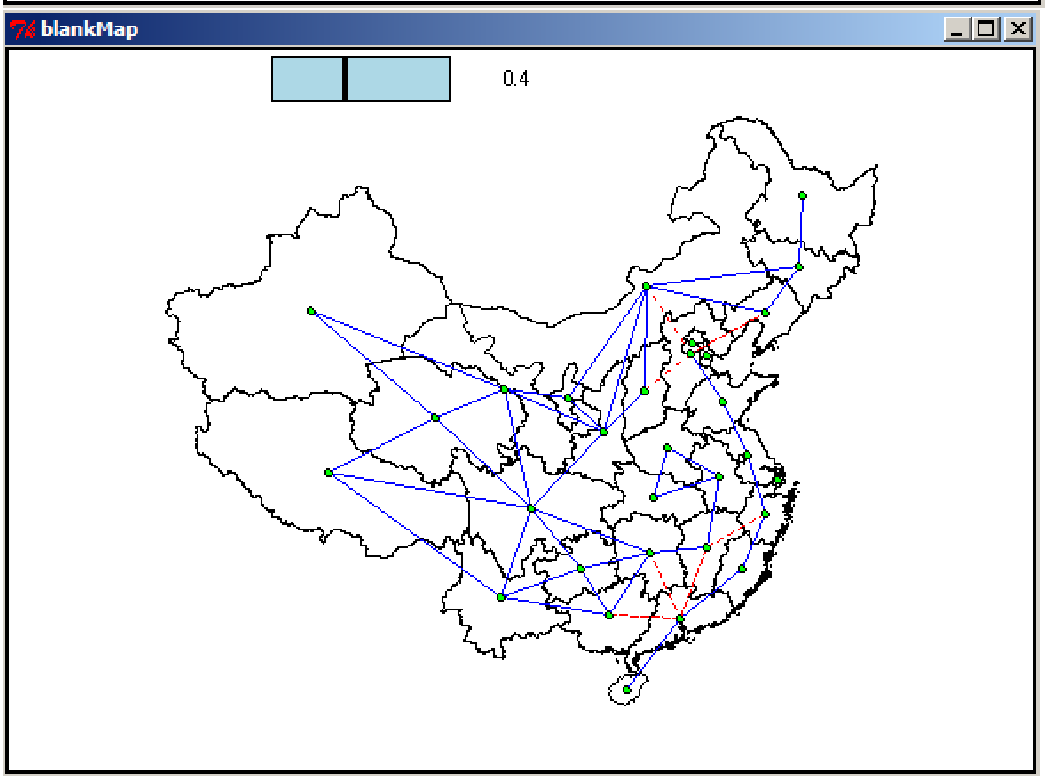
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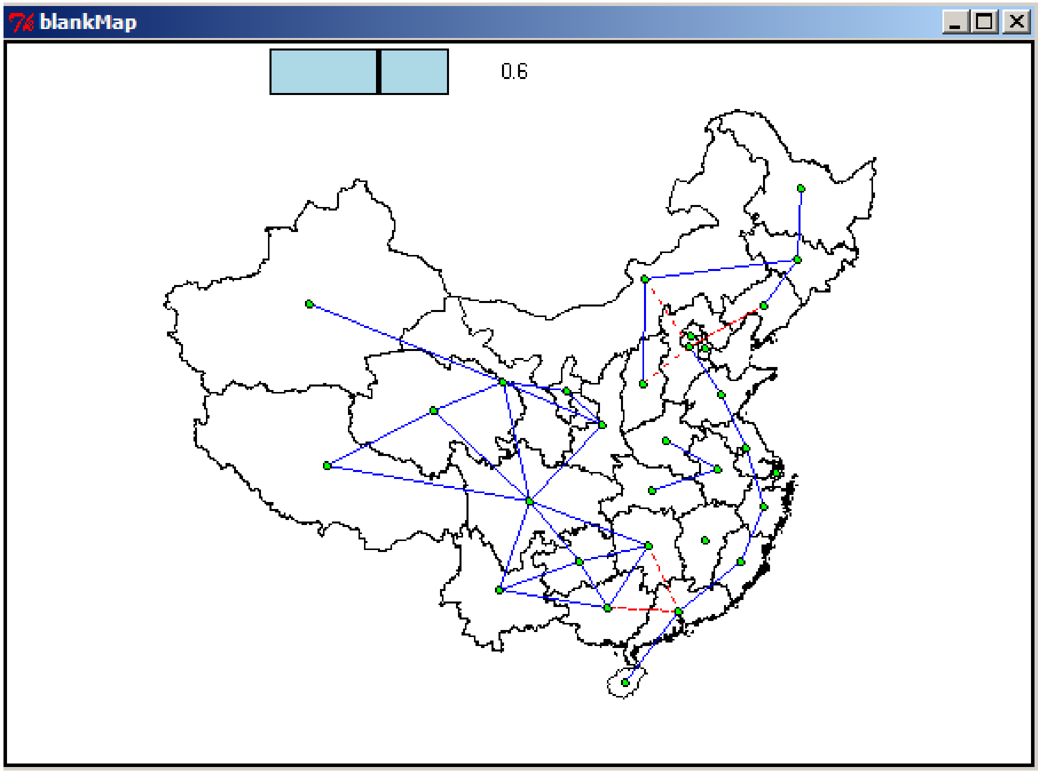


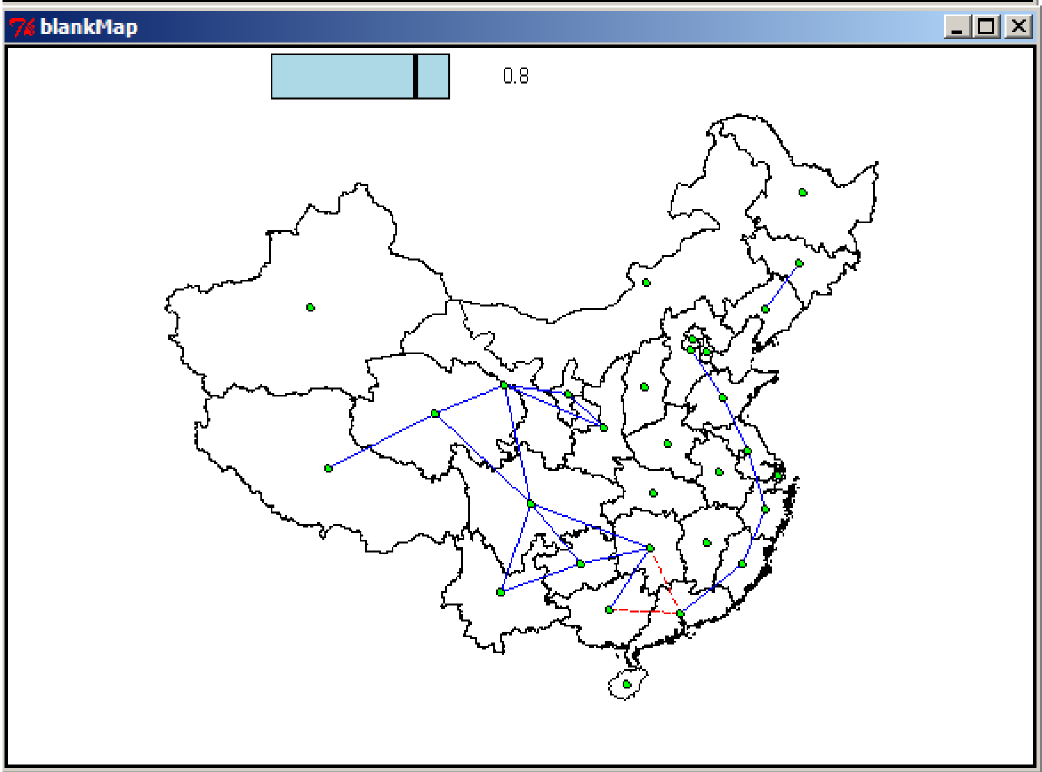
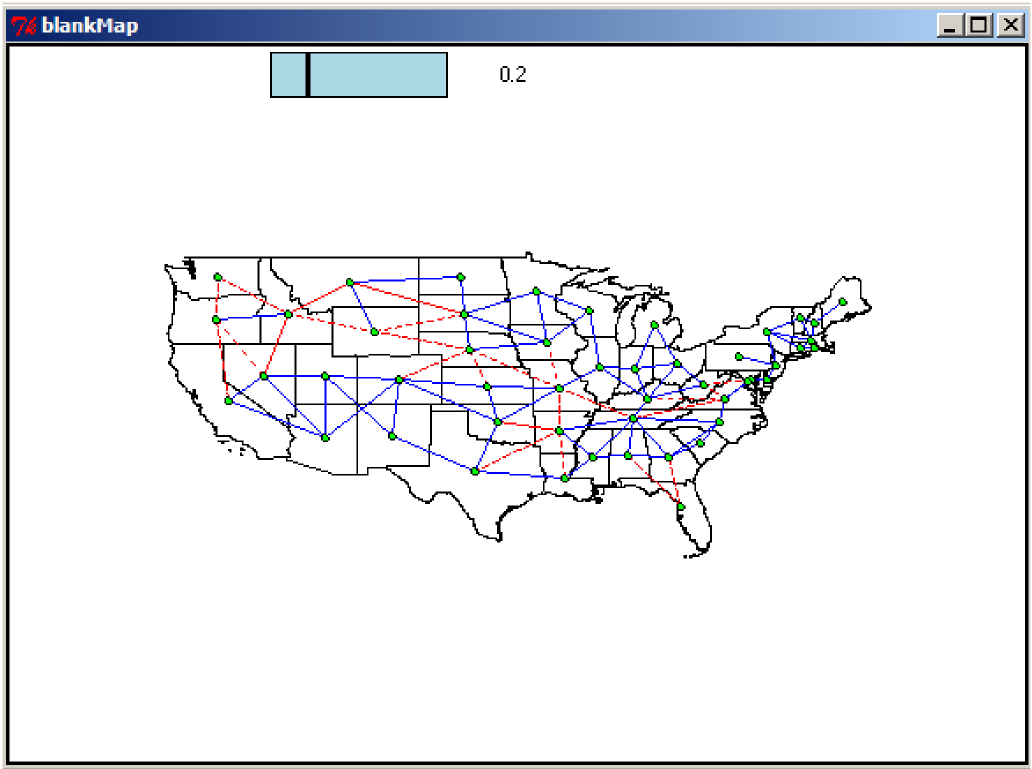


Figure 3 Snapshots of Spatial Correlation Network in China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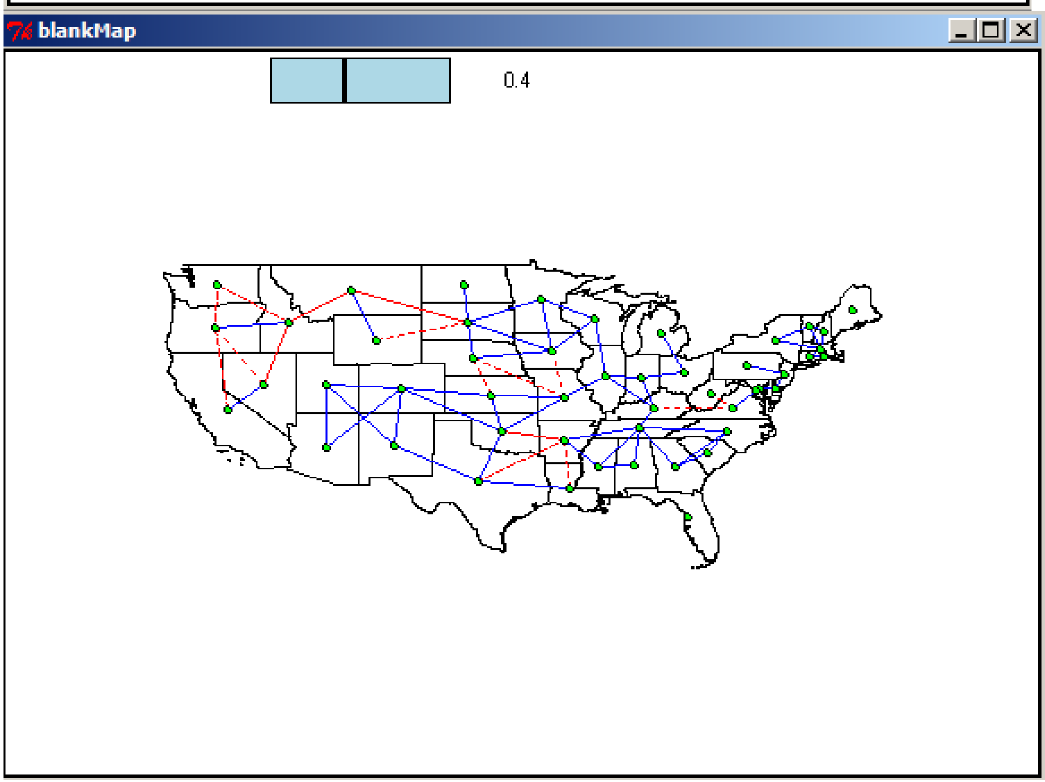
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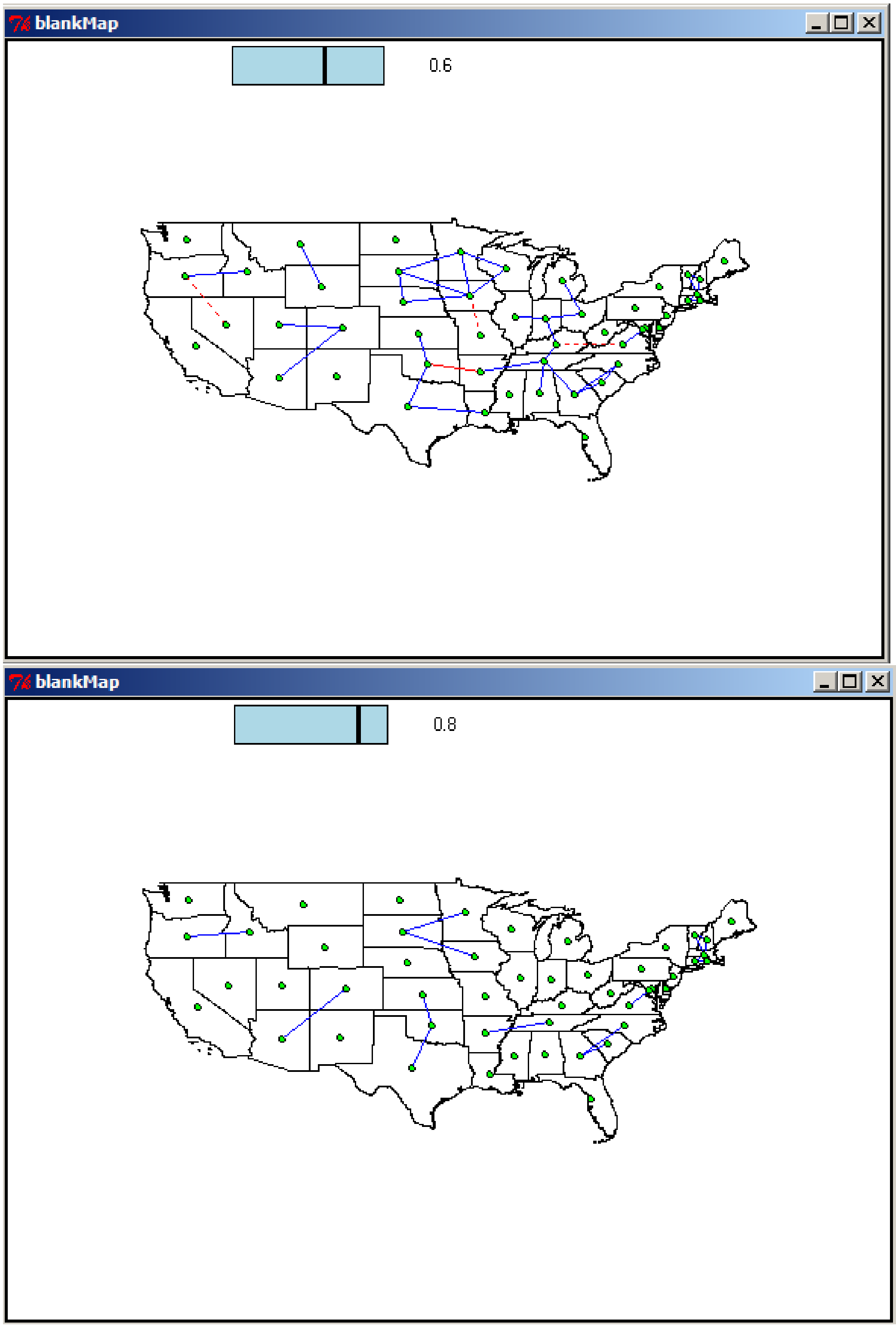
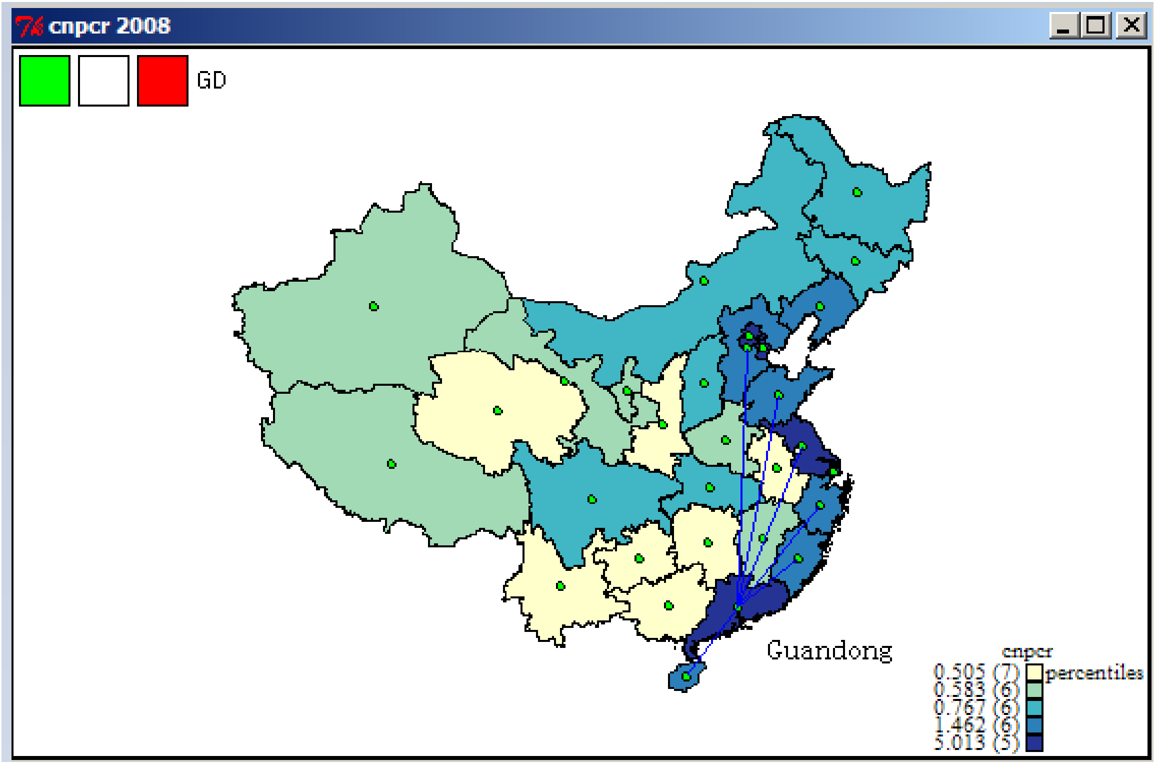


Figure 4 Snapshots of Spatial Correlation Network in the US



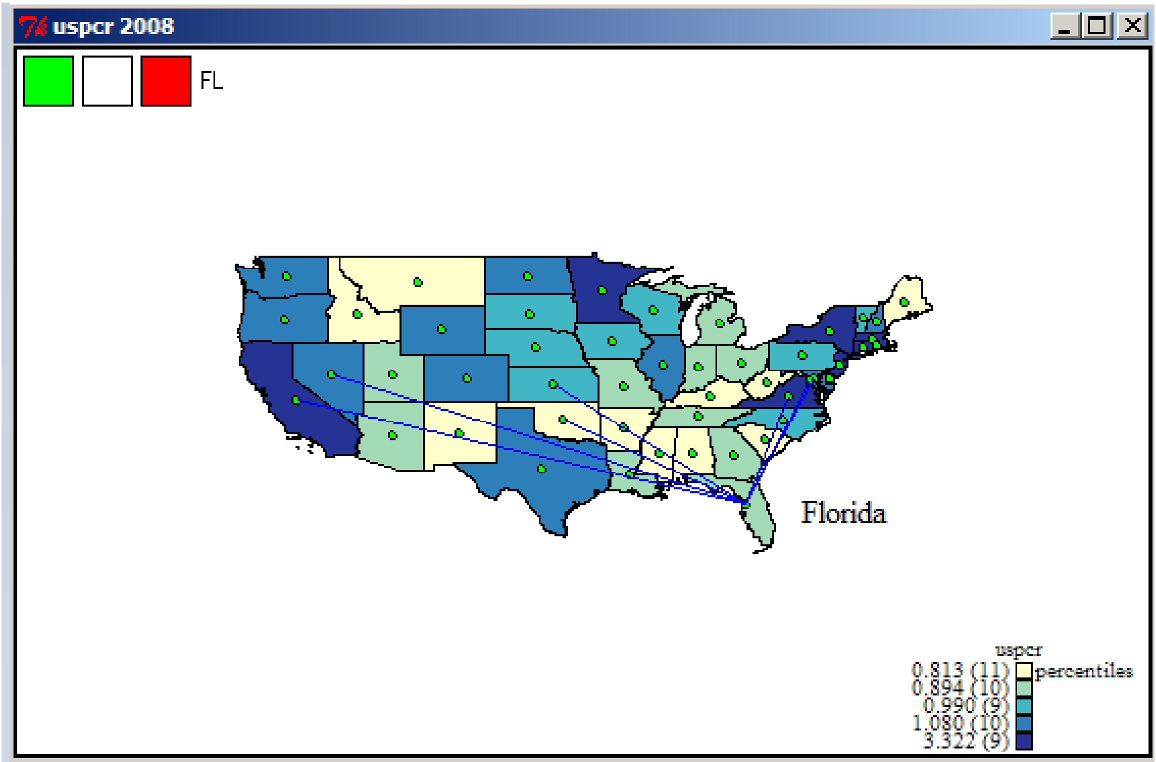
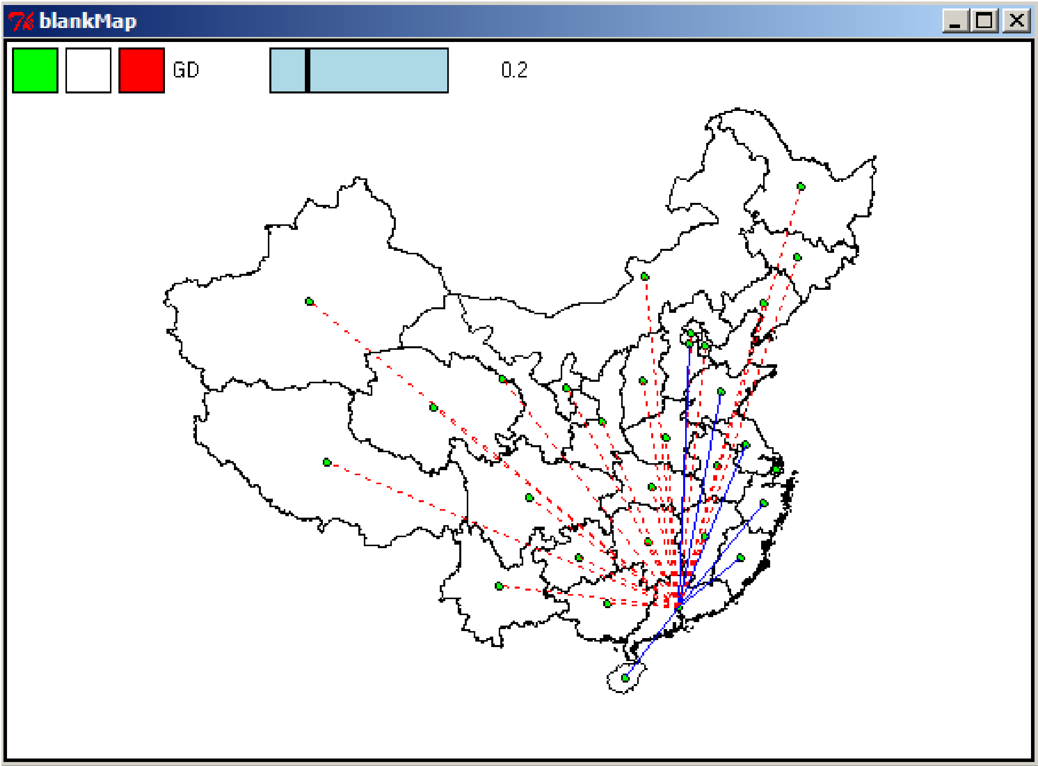


Figure 5 Spatial Spider of Guandong Province, China and Florida, the US Generated by STARS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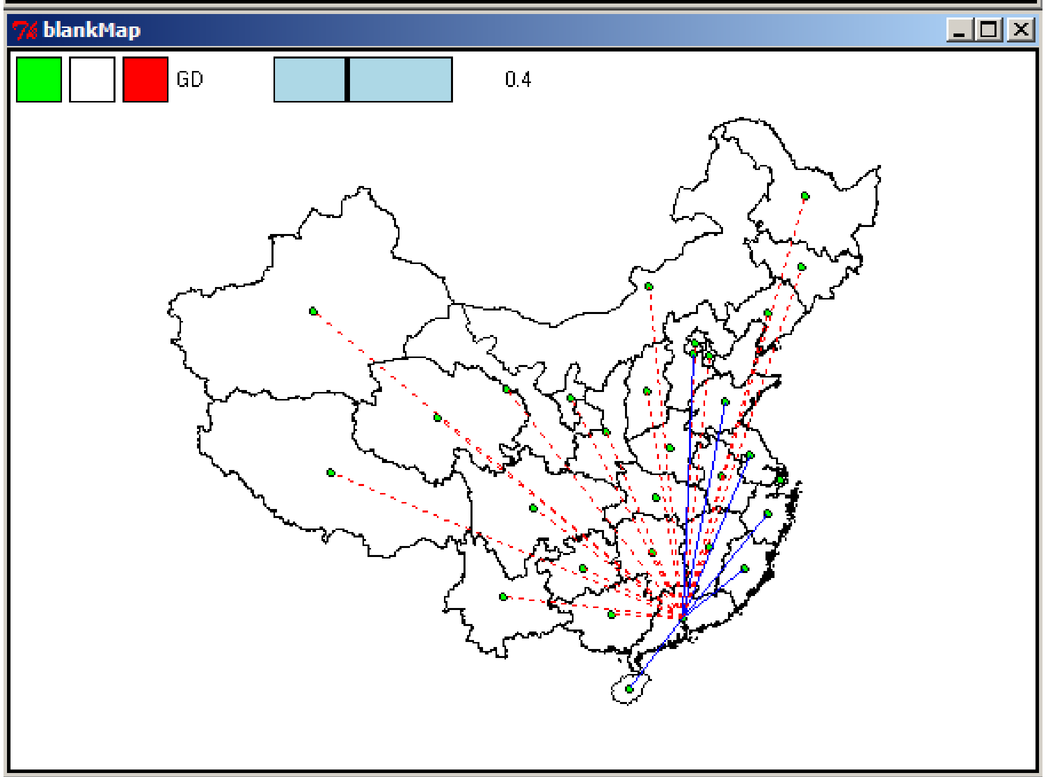
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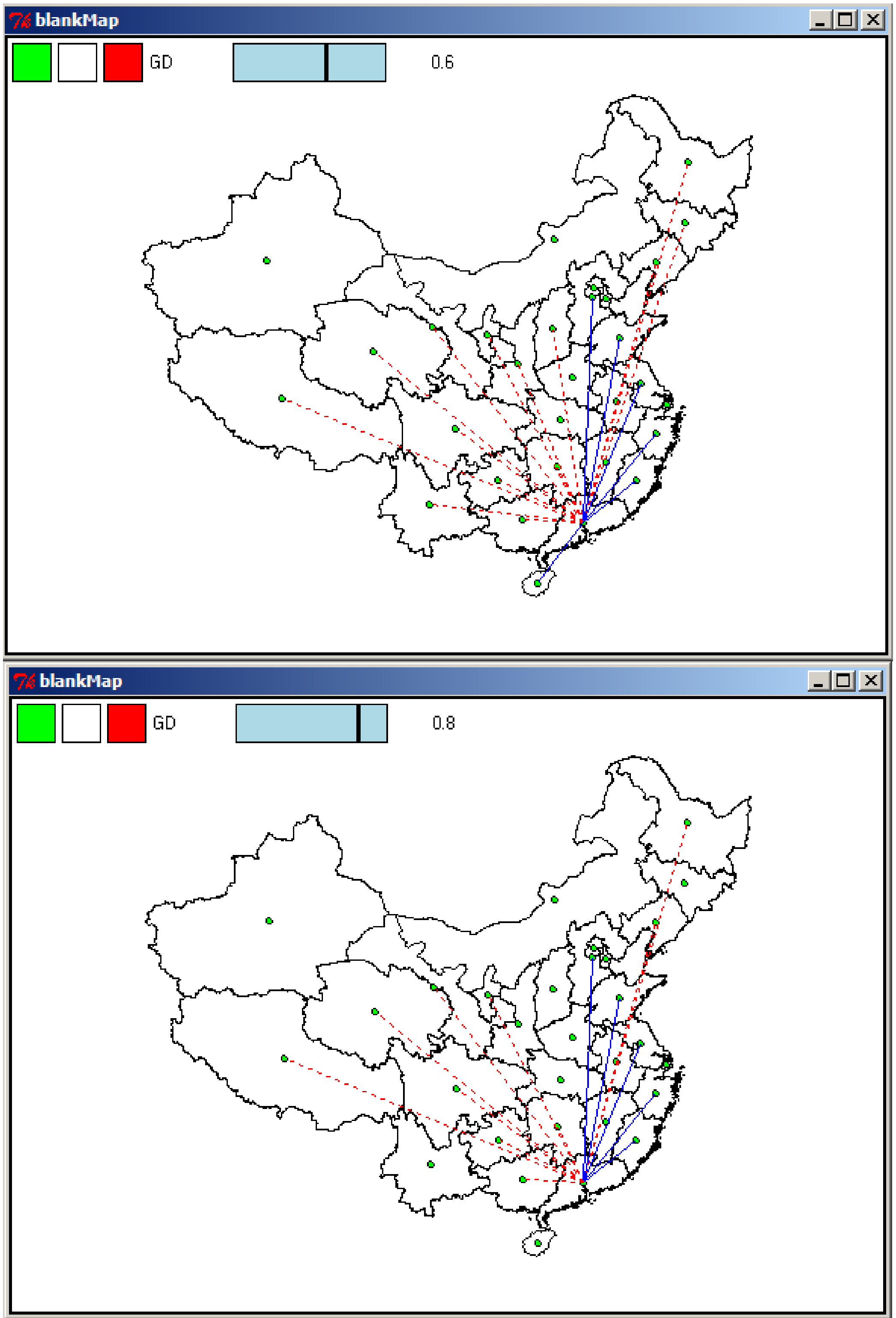
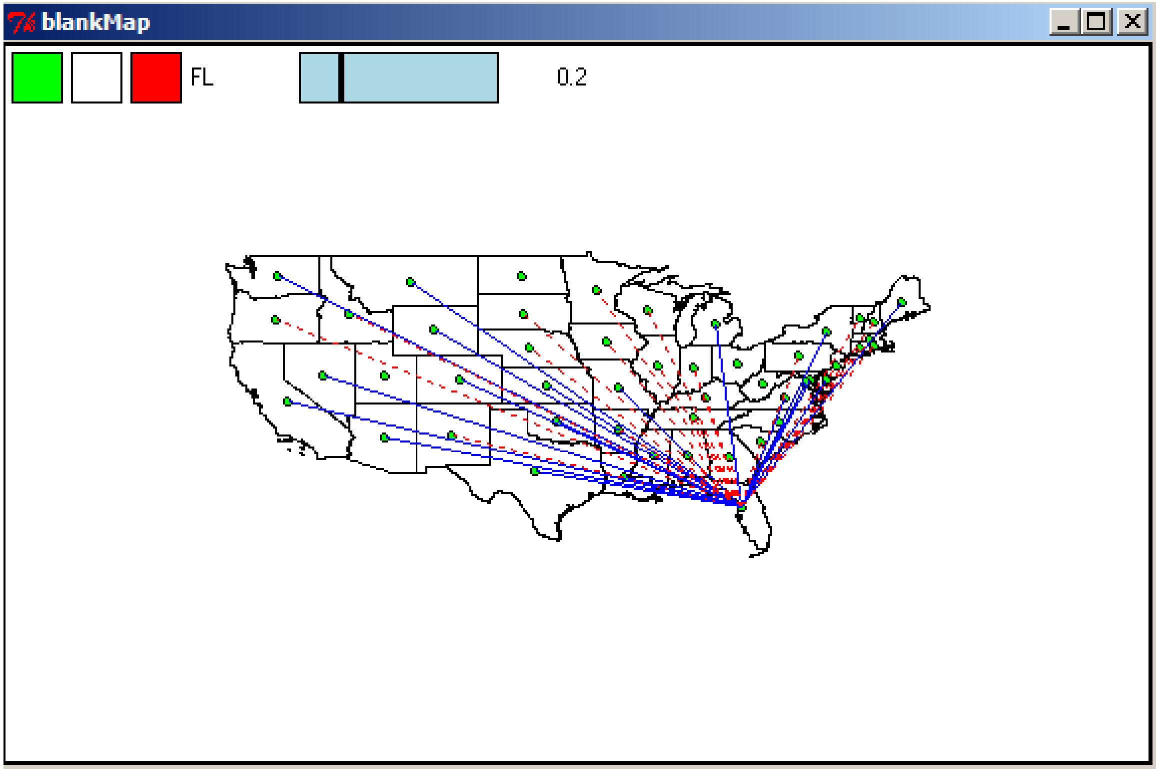


Figure 6 Snapshots of New Design of Spatial Correlation Network in China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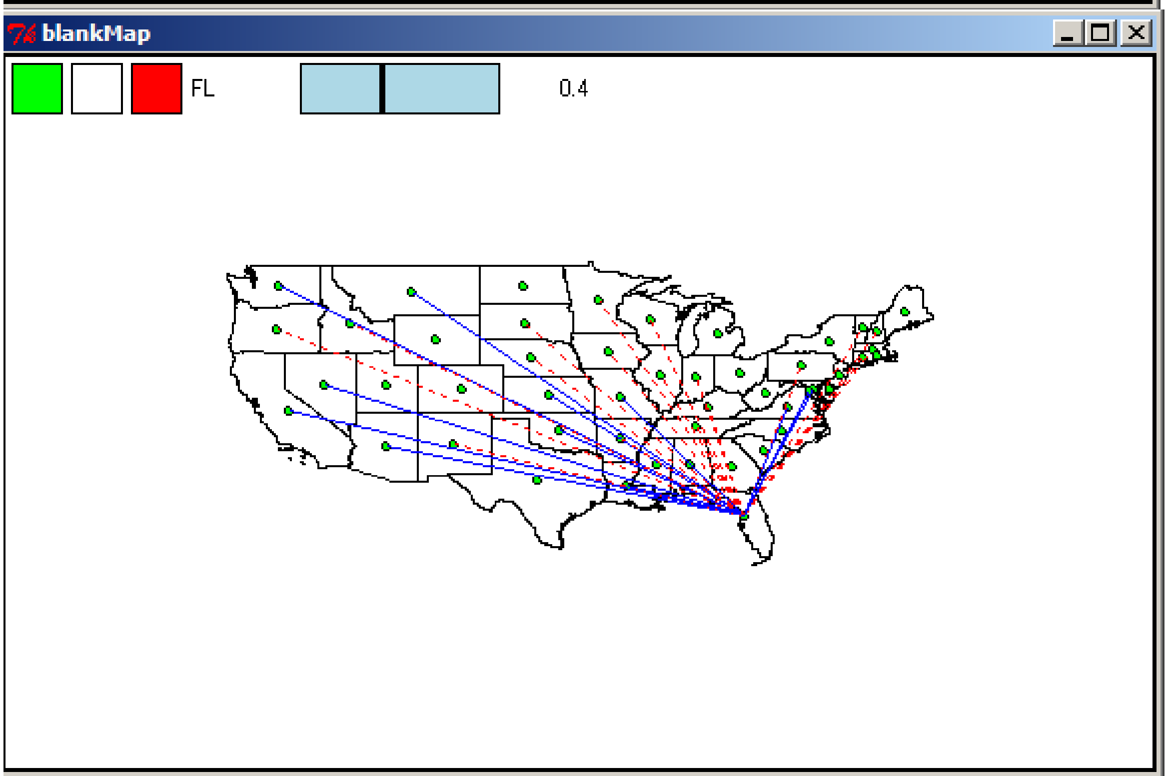
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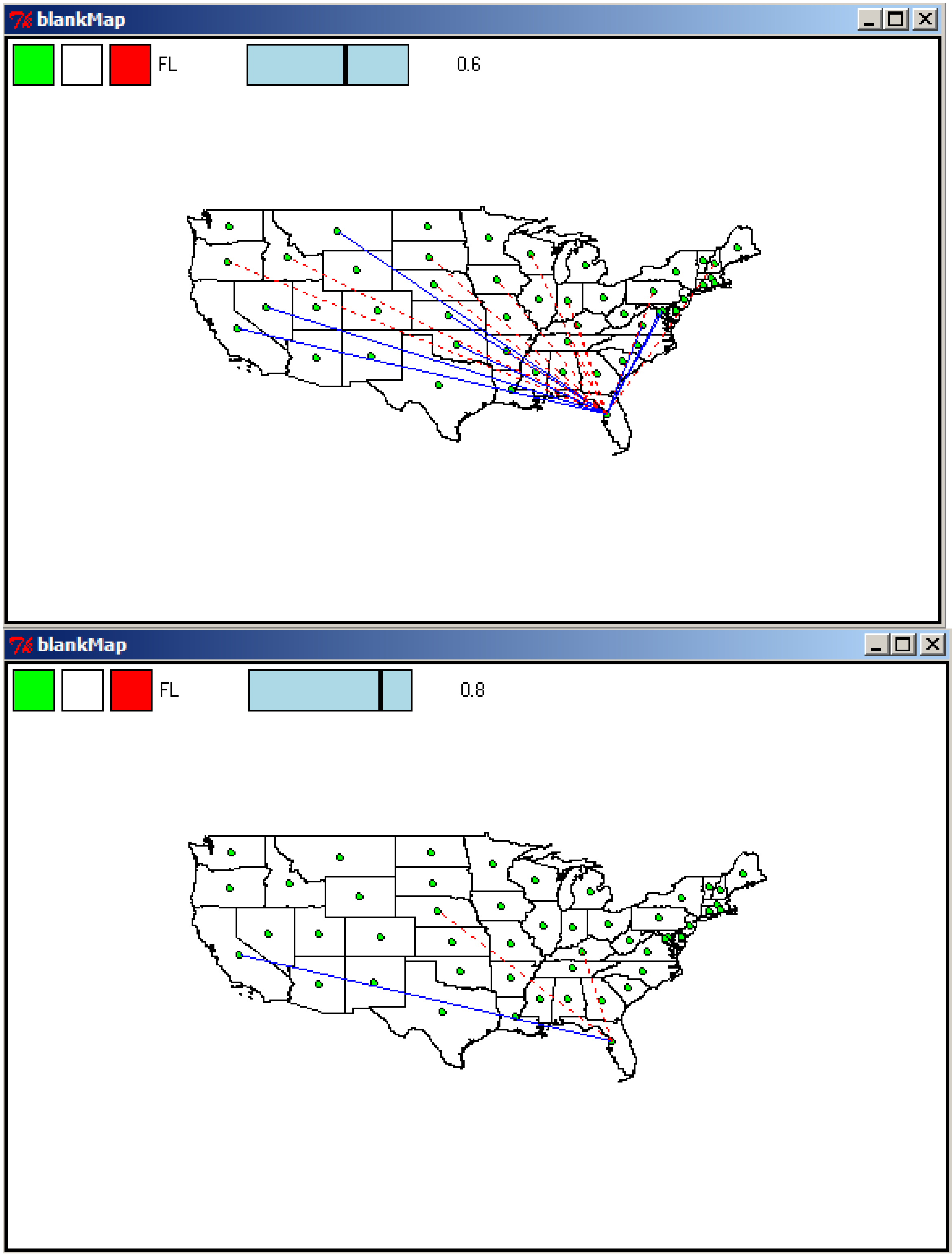
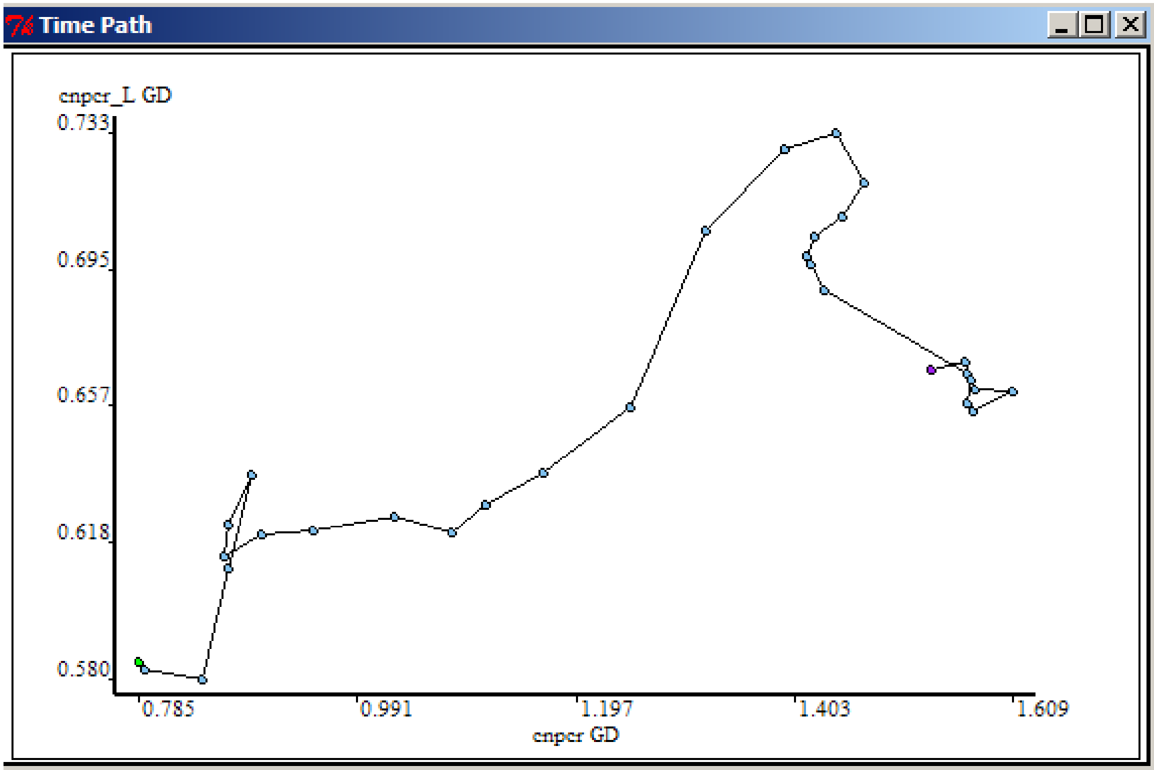


Figure 7 Snapshots of New Design of Spatial Correlation Network in the US



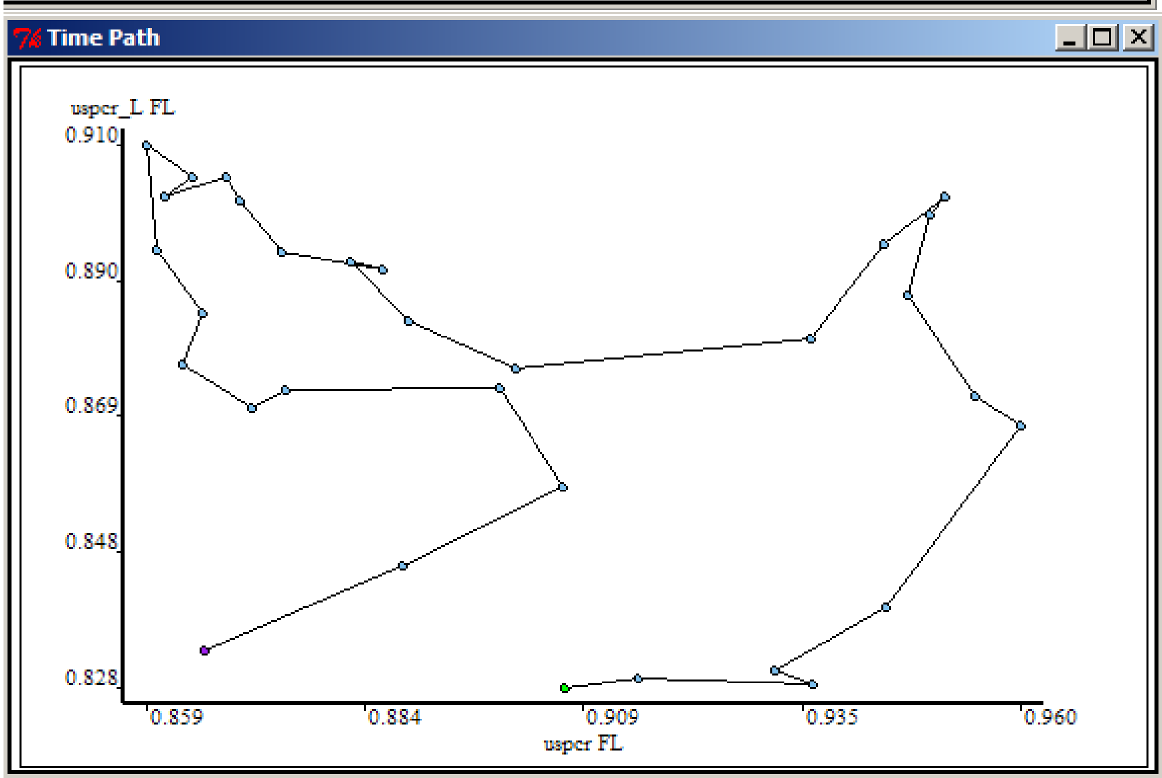


Figure 8 LISA Time Path of Guandong Province, China and Florida, the US Generated by STARS

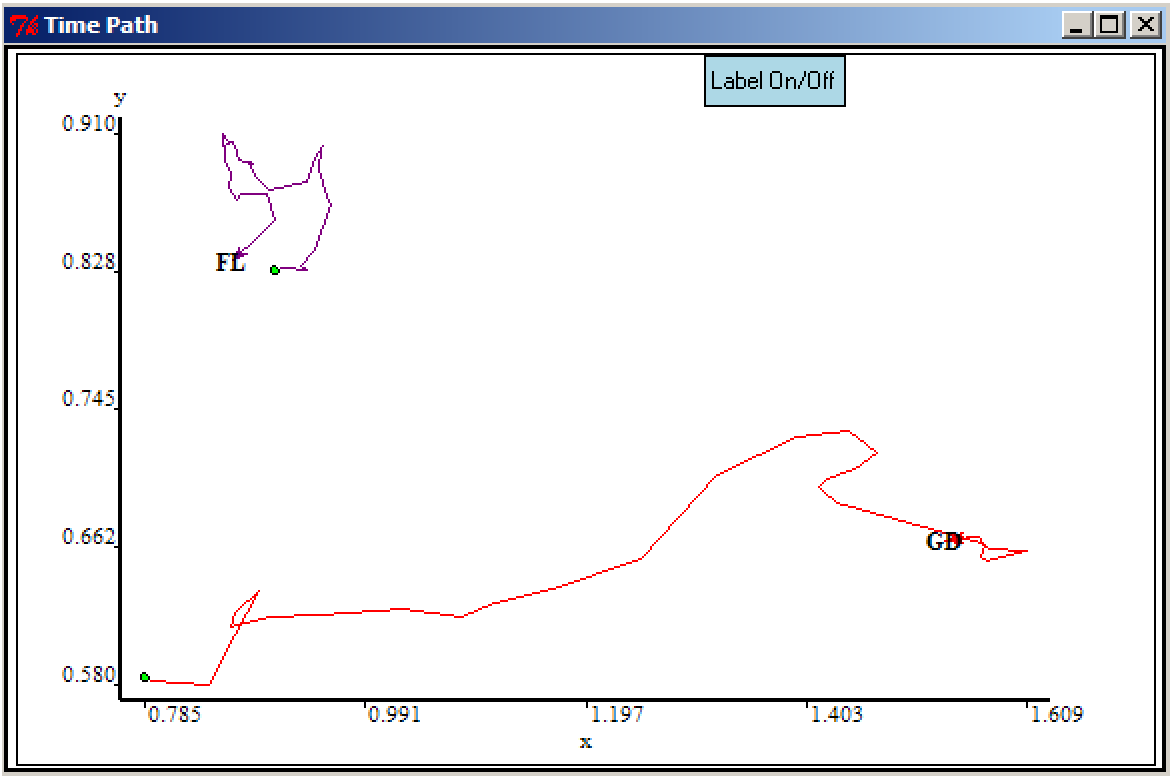
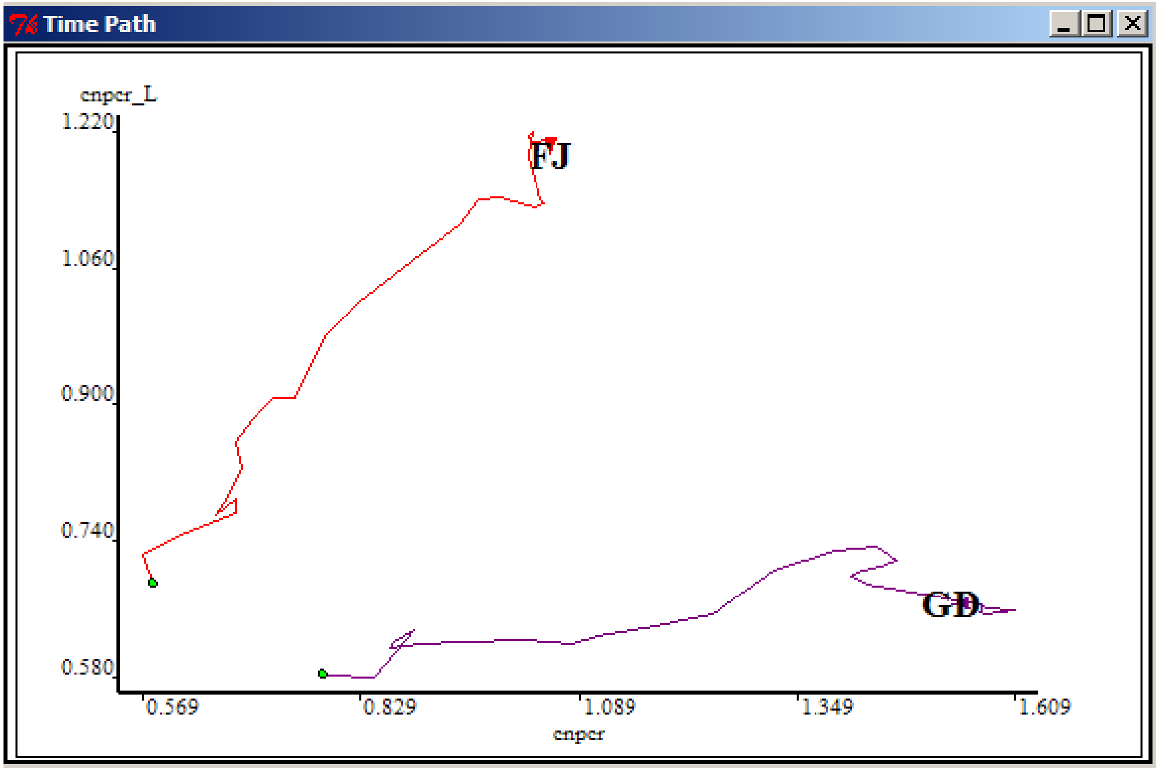


Figure 9 LISA Time Path of Guandong Province, China and Florida, the US in One Map



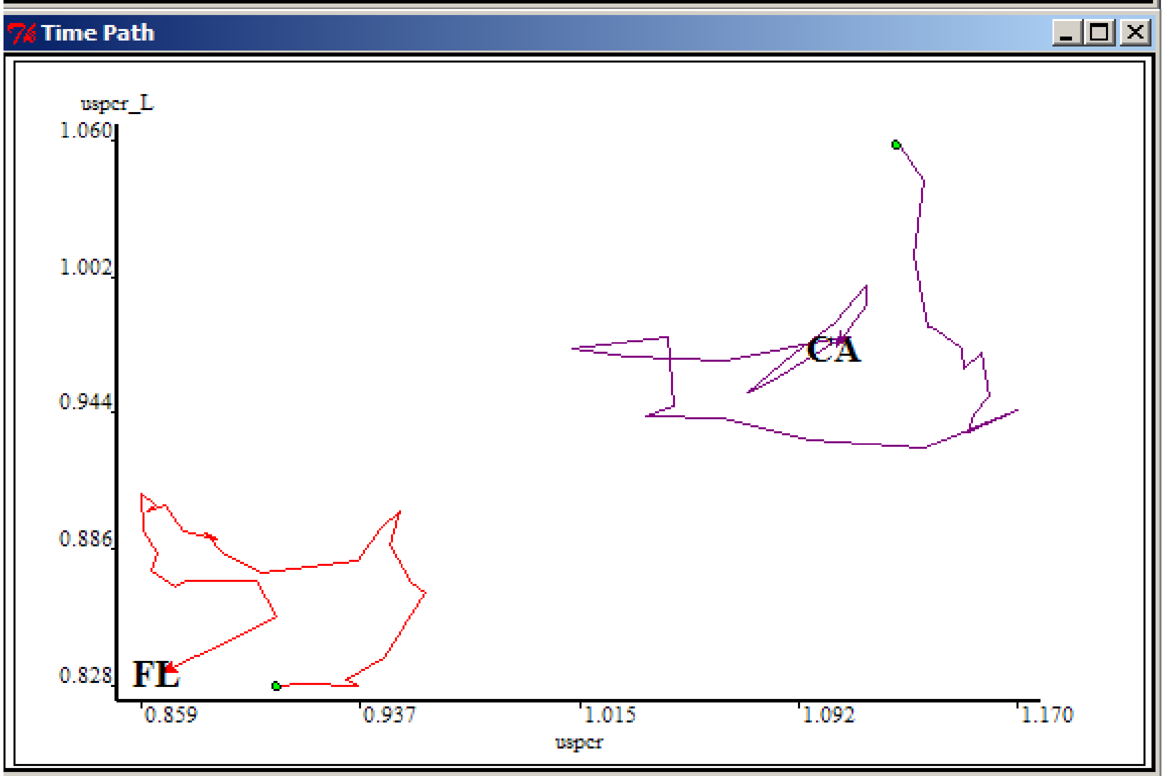


Figure 10 LISA Time Path of Guandong and Fujian; Florida and California