NUMERICAL GEOGRAPHICAL ANALYSIS IN THE CONTINENTAL SOUTHEAST ASIA

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ABSTRACT

The population density potential is a theoretical quantity to investigate distribution and movement of the human population density. By using this theory, distribution of the population density in continental Southeast Asian region is studied. The Poisson equation for potential is numerically solved on two dimensional Cartesian coordinate. The numerical method is incomplete Choleskey decomposition and conjugate gradient (ICCG) method. Large scale continental Southeast Asia and border region between north east Thailand and Laos are investigated numerically. In these models, large scale force stream to move population density along one direction is shown in the large scale model. North east Thailand and Laos model shows local potential trough. They mean that two superimposing specifications about the population density potential should be numerically considered to solve problems in this area, e.g. population, culture, topography, and so on.

1. INTRODUCTION

Numerical analyses for the population density distribution in continental Southeast Asia are carried out. This work is based on the theory for analyses about population density using "potential" (Umekawa 2009). From the numerical results, it is understood quantitatively that "force" originated the population density potential influence the population density distribution and that effects by potential distribution in local and whole region are superimposed in the large scale continental Southeast Asia model.

The force field which determines the population density distribution has two kinds of structures in this region. One is the force stream from south east to north west by the large scale calculation model. The other is the force concentrating structure to the north east Thailand and Laos. From these numerical results, the population density in this region is basically attracted by the demographically massive cities such as Bangkok, center of the region, and large implicit force stream from south east to north west.

Potential is a kind of physical quantity to investigate dynamical phenomena. This work is the application of interdisciplinary theoretical work which can be basic tools for the Geographical Information System (GIS). GIS now becomes one of the useful methods for several academic and practical researches including humanities or social studies. This study contributes new suggestion for developing GIS scheme.

Several geographical data distributed on maps, for example, population, culture, ecosystems, and so on, can be compared their common property, distributed on maps, with physical data, such as mass or electric charge. From this similarity, it is expected that the potential theory used in physics can be applied to geographical data analysis.

Continental Southeast Asia is one of the complex regions about nations, cultures,

political situations, and so on. To investigate such complex and interesting region, interdisciplinary view and method to realize them is needed.

In Umekawa (2009), results of numerical models for each continental Southeast Asian country were shown. The properties of each country in the population density potential and the structure of the forces come from the potential distributions were reported. For example, Vietnam has clear bipolar potential structure creating by demographically massive cities, Hanoi and Ho Chih Min. Laos has potential trough without population concentration. Basically, concentrations of the population density make the potential trough, and potential troughs attract population. From such system, the potential trough without population concentration in Laos is interesting and gives us new problem why such difference happened.

Here after, the application of the potential theory to geoinformatics, and analysis are explained. The numerical results are also shown to consider wide region in the continental Southeast Asia and local region around the border between north east Thailand and Laos.

In the next chapter, basics of the potential theory and its numerical style are explained. In continuous chapters, models and numerical works are shown. We summarize the results in the final chapter.

2. MATHEMATICAL AND NUMERICAL METHOD

The basics of applying mechanical theory to this work are summarized in Umekawa (2009). The Poisson equation for the population density is:

$$\Delta\varphi = b\rho, \tag{1}$$

where Δ, φ, b, and ρ mean Laplacian, the population density potential, a constant coefficient, and the population density, respectively. Laplacian is a vector analytic operator determined as:

$$\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \tag{2}$$

in two dimensional Cartesian coordinate, that means the divergence of the gradient of a scalar variable. In the Geoinformatics, the constant b can not be determined theoretically. Here we assume $b = 1.0$, so the numerical results should be considered as only relative values.

From the basic theory, the first derivative of φ mean the force acting to the population density.

To solve the equation (1), numerical method to the finite differential form of the equation (1) is needed. This equation is the second order differential equation which has boundary value problem. So the finite differential form becomes large scale linear simultaneous equations. The ICCG Scheme (Meijerink and van der Vorst, 1977; van der Volst, 1981) is employed to solve these linear simultaneous equations in the Poisson solver code. The program is written in Fortran90 by GNU Fortran90 compiler on the Linux system and Intel CPU.

The detail of practical explanations about the numerical method is described in the appendix of Umekawa (2000).

3. MODEL

The model parameters are summarized in table 1. The global population density grid data in 2000, published from Socioeconomic Data Analysis Center (SEDAC, 2007), are employed. The size of grid is 2.5' for the direction of both longitude and latitude. The number of grids in the table means two dimensional values in directions for longitude times latitude.

For simplicity, two dimensional Cartesian coordinate is assumed in the numerical calculations. Boundary conditions are zero fixed condition. Grids on sea are regarded as 0 number of population. In real fluctuation, these conditions are not exact, but under the assumption of equilibrium, they are acceptable because the time evolution is not supposed in this work.

Table 1. Models

Model	Region	Grid size	# of Grids (Long. x Lat.)	Year
1	Whole	2.5'	401x401	2000
2	Thailand and Laos	2.5'	141x161	2000

In model 2, two types of numerical results will be shown in following chapters, one is applying numerical scheme to this model region and the other is applying numerical scheme to the model 1, then cutting out the result corresponding to the region in model 2.

4. RESULT

4.1 Model 1

Figure 1 shows the numerical result in model 1, the large scale continental Southeast Asia region.

The color map layer, contour curves, and arrows mean the population density distribution, the population density potential, and the force vector field, respectively. Numbers on the axes mean the grid number. Contour curves are drawn per every forty. In the color map, blue means no data or 0 region, red is higher and white is the highest. Arrows in vector field are normalized as the length of forty grids is corresponding to the maximum value. These normalization rules are the same in all figures here after.

From the figure 1, we can overview the result of large scale model.

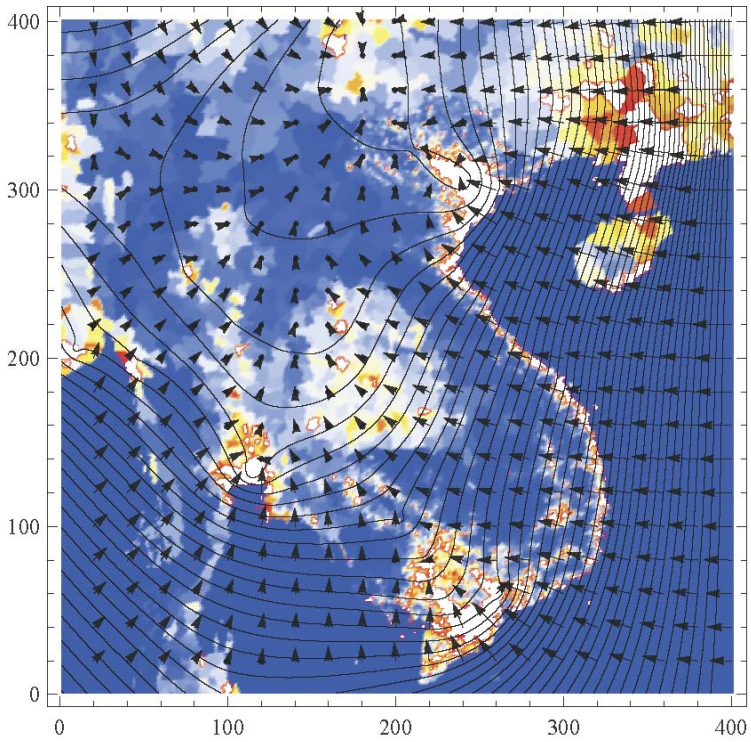

Figure 1. The result of model 1

In this scale, demographically massive cities such as Bangkok, Phnom Penh, Ho Chi Minh, and Hanoi, make clearly high density spot, and small troughs of potential distribution are shown by the curves of contours on each city. In addition, there is a low sloop of potential distribution at large scale Southeast Asian region, whose direction is south east to north west. The superposition of these to basic structure is the specification of potential structure in this region.

The population density is applied forces determined by the gradient of population density potential. Arrows show information about the force. Population density have tendency to press from south east to north west weakly, and massive cities make small scale and strong spot of attraction.

4.2 Model 2

The model 2 is shown in figure 2. In this model, the border region between north east Thailand and Laos are calculated. The massive population density around the number of grids (10, 30) is Bangkok, (60, 130) is Vientiane, and so on.

Different numerical conditions make different potential distributions. Figure 2 shows a potential trough covering center of the figure, which includes north east Thailand and Laos partially. There are not massive cities in the area, but spatial concentration region. It is almost corresponding to the position of potential trough shown by contour curves. This figure suggests that north east Thailand and its marginal regions within Laos have some kinds of relations on population and human streams.

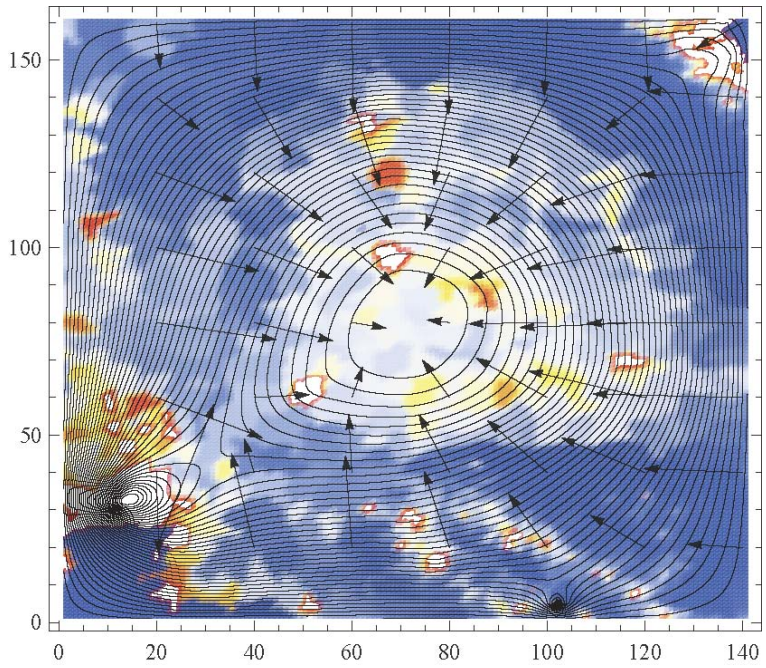

Figure 2. The result of model 2

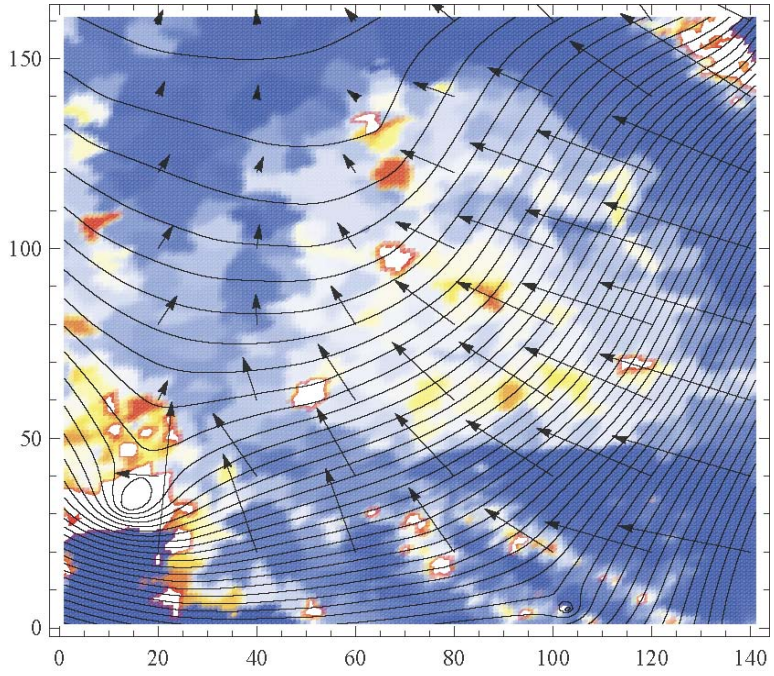

Figure 3. The partial image of model 1 corresponding to the region in model2

Figure 3 shows the cut out and redrawn image of model 1 of the same region with model 2. This figure shows large scale force stream from south east to north west. Only some

massive cities can transform the shape of contour curves of the potential and force field vectors. It is the large scale phenomenon. On the other hand, results shown in figure 2 are derived from the phenomenon in north east Thailand and Laos local region. From the comparison figure 2 with figure 3, spatial concentration of population density in north east Thailand and Laos influences force field locally.

5. SUMMARY

Numerical analyses by using population density potential are applied to the continental Southeast Asia.

In model 1, the image of the large scale Southeast Asian region, large and weak force stream on the direction from south east to north west is shown. Population in this region is forced to move from south east to north west. However, demographically massive cities create relatively deep potential troughs. They transform the shape of population density potential distribution. People can remain by this variant on the potential field.

In model 2, numerical result in the region around the border between north east Thailand and Laos is shown. This result shows the spatial dense population region in north east Thailand create local potential trough. This trough may locally attract population. This result also describes transborder links of north east Thailand and a part of Laos. Relation between this local effect itself and large scale force stream come from model 1 should be considered in future works.

As one of back ground attractors to make large force stream shown in model 1, massive cities in other countries especially in China, which are out side of the model region, can be expected. However, it will study carefully in the next step.

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