Comparison Analysis of Temperature Change between Georgia and California

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Abstract

Global warming has been a heated topic in recent decades and it is shown that the average temperature of U.S. has been increasing since 1901 and more quickly from the 1970s. However the data reveals that on a state level a different temperature change pattern exists and some areas might experience cooling during coming decades. This paper uses a SVAR model to analyze the different temperature trends of two representative states, Georgia and California, and identifies the possible factors and causes of these differences.

Key words: Global warming, Temperature change, SVAR Model, Variance decomposition, impulse response function.

Introduction

Climate change has been a heated topic in recent decades, especially the issue of global warming. Among the broad scope of climate, temperature is a fundamental component and a key reflection of its change, which can have wide-ranging effects on human life and ecosystems. Temperature patterns also determine what types of animals and plants can survive in a particular place. Changes in temperature can disrupt a wide range of natural processes, including agricultural production, particularly if these changes occur abruptly and plants as well as animal species do not have time to adapt (U.S. EPA, 2012). It could also bring significant impacts on industry and people's everyday life. All these effects drive more and more research work into the related fields.

Research shows that global average surface temperatures have risen at an average rate of 0.13°F per decade since 1901. Similarly, temperatures have risen across the lower 48 states of the United States at an average rate of 0.13°F per decade. Furthermore, the average temperatures have risen more quickly since the late 1970s (0.35 to 0.51°F per decade) (U.S. EPA, 2012). It seems that the whole US is experiencing the warmer weather. However, based on the time series plot of average annual temperature in last century for different regions in US one may find some different conclusions: in the western part of the U.S. (e.g., California) the temperature did continuously rise in recent decades (Figure 1), while the eastern part of the U.S. (e.g., Georgia) actually faces a descending trend (Figure 2) which is opposite to the expectations of believers in global warming. This contradiction and the factors behind it are the thrust of this research.

This paper chooses two typical states mentioned above from western and eastern part of the US - California and Georgia and examines the temperature trends in each of them during

recent decades. The analytical results demonstrated the phenomenon one observed from the temperature graphs that these two states demonstrated opposite trends in the recent century. Then we focus on identifying the factors that may cause the differences of changing pattern between the two states, which basically include the natural and anthropogenic aspects. The time series model used in this research will also reveal how the temperature will respond to shocks on these factors as well as the magnitude of the response.

Results from this paper provide a clear description of temperature change in the two states, which can be generalized to a broader area. Knowledge of the key factors that may affect climate change on different levels provides insights that allow the concentration of efforts in areas most likely to be effective to improve the local climate.

Data and Methods

This paper concentrates on analyzing the variation of the land air temperature of the two states, and the data includes the land, air, and sea surface temperature, vegetation cover area in the two states (Los, Sietse O. et al., 2001), as well as sun spot numbers which is considered to be a representation of solar irradiance that is highly related to air temperature (Friis-Christensen and Lassen, 1991). The annual petroleum consumption in manufacturing and the transportation sector is considered a measure of the effect of human activities, since the major emission of gas use is carbon dioxide which is the major component of greenhouse gases that may seriously affect the climate. All the data are annual averages from 1950 to 2011 (the air temperature data of the two states are from 1900 to 2011 since it is needed to describe the long run trend in the first part of the analysis). The temperature data come from the national climate data center at

NOAA. The original data are collected frequently from several climate stations located in the central part of the two states, basically at the same latitude, then averaged to annual records. The forest land area in the United States is used to describe the land surface vegetation since forest is its major component part of it, and the data comes from the forest resource report published by the U.S. Forest Service. The forest area data is only published every 7 to 10 years; missing data points are estimated using spline interpolation. The sunspot data come from the National Aeronautics and Space Administration. The U.S. Energy Information Administration is the source of the detailed data of petroleum consumption in different sectors in the period. All the data are log-transformed to make the magnitudes conformable and explanation convenient.

The analysis can be divided into two parts. First a linear model was fitted to detect the temperature trend of the two states during the last century which can be determined by the sign of the slope. The magnitude of this long term change can also be calculated from this model. This is a preliminary analysis and a brief view of the implicit changing pattern of the temperature.

The structural vector autoregression model is followed in this study and applied to analyze the data in two states separately. The theoretical model is:

$$\mathbf{A_0 y_t} = \mathbf{B_0} + \sum_{i=1}^{p} \mathbf{B_i y_{y-i}} + \mathbf{u_t} \qquad (1)$$

in which $\mathbf{y_t}$ includes the six variables for each state and $\mathbf{A_0}$, $\mathbf{B_i}$ are the 6 by 6 coefficient matrices. Restrictions need to be applied in order to identify the system. As mentioned before, the changing trend of land air temperature is the major concern of this study so all the other five factors, sea surface temperature, petroleum consumption in the manufacturing and transportation

sector, the forest area and number of sunspot are designed to affect the air temperature. Meanwhile, due to the fluidity of CO_2, which is the major emission of petroleum use, it is reasonable to assume that the manufacturing and transportation activities will affect the sea surface temperature as well. The manufacturing and transportation sectors should not be affected by temperature. For forest cover, the temperature and different levels of human activities are all considered to be related except the sunspot amount. At last, the activity of sun is assumed completely exogenous to the system.

After estimating the SVAR model, innovation accounting (variance decomposition, VDC and the impulse response function, IRF) was performed to analyze the effects of different factors on the variation of the air temperature. Forecast error variance decomposition is based on determining the component of the variations in a time series variable, i.e., the proportion of variation caused by its own shock and by shocks to the other factors in the system (Brandt and Williams, 2006). The original model was interpreted to vector moving average form and the forecast error was calculated over the time horizon. The importance of the distinct explanatory variables can also be viewed from this process. If the innovations of the variables of interest are not explained much by a factor, one can deduce that this factor is exogenous or not a significant cause of the response variable. On the contrary, if two variables are contemporaneously correlated, it is expected to see that variation in one variable contributes highly to the other.

Another method employed in this study is examination of the impulse response function (IRF), which traces out the dynamic impacts to the response variable of shocks from the explanatory variables over time. Thus, the IRF characterizes the dynamic behavior of the time series. It provides a direct, clear graphical summary of the complex dynamic system used to

explain the multivariate system (Brandt and Williams, 2006). Meanwhile, the shocks to the response are expected to die off gradually due to the stationary property of the series; in addition, whether the shocks differ significantly from zero is also important. One valid method to consider this is to set up the confidence interval of the response to the shock (more precisely, 1 standard deviation shock). However, due to the difficulties such as no guarantee of the finite sample distribution (Lutkepohl, 1990) and possible existence of serially correlation between responses to the shocks, it is complicated to derive the variance of the impulse responses analytically, so is setting up the confidence intervals. Thus in this paper, the bootstrap method was utilized to simulate the confidence band for the impulse response functions.

Results

The results of the fitted linear model show that the temperature of California during the past century changed almost 1.5 F with an increasing trend, while the case in Georgia is just the opposite – the temperature trend was decreasing and changed about -0.8 F. These results are consistent with visual inspection of the data.

Prior to performing the variance analysis the number of lags of the series was chosen using the SBIC criteria. Augmented Dickey-Fuller and Phillips-Perron tests were carried out on the series to check stationary and the results indicated that the original level data is suitable for the model. The forecast error variance decompositions for the first 5 years of air temperature based on the other five factors in the two states are listed in Table 1 and Table 2. Note that each row in the tables corresponds to one period, in this case, one year in the forecast horizon so each row should sum to 1. For both Table 1 and Table 2, the initial shock to the air temperature is all due to itself, and in the following periods, it still significantly contributes the largest proportion

of innovation to itself. This is the same for both states although in California the proportion is larger.

Table 1 indicates that the most significant factors that contribute to changes in air temperature are itself and sea temperature, which explain almost 98% of the variation. By the fifth year, about 5% of the change in air temperature is due to the other four variables: forest change (0.2%), petroleum consumption in the manufacturing sector (2%) and the transportation sector (1%), and unpredictable sun activity (1.6 %). Notice that the effect of forest area continues increasing although it's not statistically significant.

For the California results which are listed in Table 2, one distinction is that the sea temperature is no longer significant and contributed much less to the variation of air temperature compared with Georgia. The forest cover area becomes statistically significant and the ratio it takes on is continuously raising; by the end of the 5^{th} year, about 5% of the variation in the air temperature is due to forest area. The petroleum consumption in the manufacturing sector takes about 12% yet is not significant.

The analysis proceeds to impulse response functions of the two states which are plotted in Figure 3 and Figure 4, respectively. Only the IRF of air temperature is shown since it's the topic this paper focused on. Each graph demonstrates the responses of temperature to a one standard deviation shock to the error of explanatory variables, whose name is listed in the title. In order to investigate the pure variation caused by every variable, the orthogonalized IRFs are plotted here with a 90% confidence interval band calculated by bootstrap method. For Figure 3, the Georgia case, the largest variation source is air temperature itself, whose response is increasing about 1% when the own shock happens, then decreases and gradually dies off with time continuing. A

shock to sea temperature will lead the air temperature about 0.5% higher after the shock happened. The air temperature does not respond to shocks in petroleum consumption in the manufacturing or transportation sector since the 90% confidence bands include zero. Forest area however, has a significant positive effect on the temperature when the shock initially occurs, but the effect fades away quickly. The last graph shows that a change in sunspot numbers does not influence the temperature significantly.

On the other side, the California IRF suggests some differences compared with Georgia (Figure 4). Although the largest response of air temperature is still caused by its own shock (1% increasing when shock happen), a sea temperature shock is not significant for California. A shock from petroleum use in the manufacturing sector is significant and causes a temporary approximate 0.3% increase in temperature, with this influence vanishing after five periods. The effect of forest land area is more interesting. From the first graph in Figure 4 one can observe that after a one standard error shock in forest area (which is quite a large area), the temperature rose by 0.2% one period after the shock happened. The curve continues descending however, until about 12 years later it shows a significant negative influence on the temperature. The confidence band of sun activity is wide and includes zero for all time periods so it does not have a significant effect to the temperature.

Both the results of the variance decomposition and the impulse response function suggest that the major determinants of land air temperature are its own past values and nearby sea surface temperature, no matter in Georgia or California. The other variables listed in this study only contributed a small proportion although some of them are significant. However, it is still worth investigating the differences and implications between the two states. One disparity is the IRF graph which shows that the petroleum consumption in the manufacturing sector of California is

significant, while in Georgia it's not. A possible explanation is that California has a larger industry and population than Georgia so the amount of CO2 emitted by the manufacturing sector in California is large enough to affect the temperature. More specifically, in the year 2011, manufacturing's production value (calculated from GDP) in California is $989 billion (2005 dollars), while this number is $139 billion in Georgia (U.S. Bureau of Economics, 2011), which is only one seventh of California's. This difference in scale can also be seen from the petroleum consumption data used in this study- the annual gas use in California industrial sector in year 2010 is 72,878 thousand barrels (or 445.2 barrels per square mile), while this number in Georgia is 16,173 (or 272.16 barrels per square mile). Thus the big gap between the petroleum consumption may be the causes of the different effects on the temperature.

The effect of land forest area is also worth investigating. Trees and forest help remove carbon dioxide from the atmosphere and store it as carbon in their biomass through photosynthesis (Goulden, Michael L. et al., 2004). Meanwhile large forest areas can efficiently adjust the moisture and regulate the water which is helpful to lower the temperature. However one prerequisite is that trees should be mature enough (with large leaves) and the forest area needs to be broad enough to have a noticeable effect on the climate. So when there is a shock to the forest area, for example, land is reclaimed to plant trees, the original biomass (like grass) on the land may be destroyed, worsening the local ecosystem temporarily; and also the newly-planted immature tress cannot fully functionalize in decomposing of CO_2, on the contrary it may produce more during respiration. This could explain why in the first several periods the response of temperature to a shock to forest area is positive. Clearly as the trees grow and form a broad forest, they can effectively lower the local temperature. This coincides with the IRF decreasing in later periods and about 12 years after a shock having asignificant negative effect on

temperature. Notice that the patterns of the IRF for forest area are almost identical between the two states (except, for California, it is more significant), which shows that the response of temperature to the shock in forest follows the same principle. Another situation may cause the insignificance of forest area as a factor in Georgia: that the state already has quite a large land vegetation area. According to the data, timberland covers 64.2% of Georgia while only 17.9% of California is covered. Also, a large area of Georgia's neighboring states is also covered by forest, which provides additional benefits. This may briefly reduce the effect caused by a changing in local vegetation, which could lead to the insignificance of response of temperature to a shock to forest area.

Conclusion

This study shows that some areas might experience more warming than others, while some might experience cooling during coming decades, so it is not wise to judge global warming as if it is a uniform event. However, there are some key factors that appear correlated with temperature and can be controlled by humans. Increasing forest area appears to be a beneficial policy to lower temperatures, especially in long run, large area of woods will significantly affect the temperature in a positive manner. One piece of evidence related to this is that from 1907 to 2007 the forest area in Georgia and neighboring states have been continuously increasing while in California it is the opposite, the forest area has reduced by over one million acres. This may be due to the more rapid development in California. This leads to another implication of this study that the scale of industry is another factor highly related to the local temperature change. Probably more reasonable industrial layout and more clean energy utilization in the industrial process may help to control and mitigate the effects of this variable to the climate. However, the effect of petroleum consumption in industry in this research only shows significance in California, not

Georgia. So an important finding of this study is that analyzing the impacts of potential climate change needs to be done on a more micro, or regional level, rather than policy makers acting as if climate change was a phenomenon that impacts the whole world in an uniform manner.

Table 1. Forecast Error Variance Decomposition of Air Temperature in Georgia

Percent of error variance of	**Period (year)**	**Shocks in**					
		Air Temp	Sea Temp	Forest	Petro. Ind	Petro. Tran	Sunspot
	1	1	0	0	0	0	0
Air	2	0.746*	0.237*	0.000718	0.0173	0.00958	0.00615
Temp	3	0.731*	0.229*	0.00154	0.0173	0.00931	0.0119
	4	0.719*	0.233*	0.00183	0.0193	0.00995	0.0159
	5	0.714*	0.239*	0.00195	0.0192	0.00925	0.0163

"*"indicates the 95% confidence interval of this VDC does not include zero;

Table 2. Forecast Error Variance Decomposition of Air Temperature in California

Percent of error variance of	**Period (year)**	**Shocks in**					
		Air Temp	Sea Temp	Forest	Petro. Ind	Petro. Tran	Sunspot
	1	1	0	0	0	0	0
Air	2	0.948*	0.00209	0.0271*	0.00423	0.0149	0.00349
Temp	3	0.844*	0.0166	0.0453*	0.0746	0.0143	0.00476
	4	0.792*	0.0239	0.0512*	0.115	0.0134	0.00451
	5	0.781*	0.0239	0.0537*	0.124	0.0132	0.00469

"*"indicates the 95% confidence interval of this VDC does not include zero;

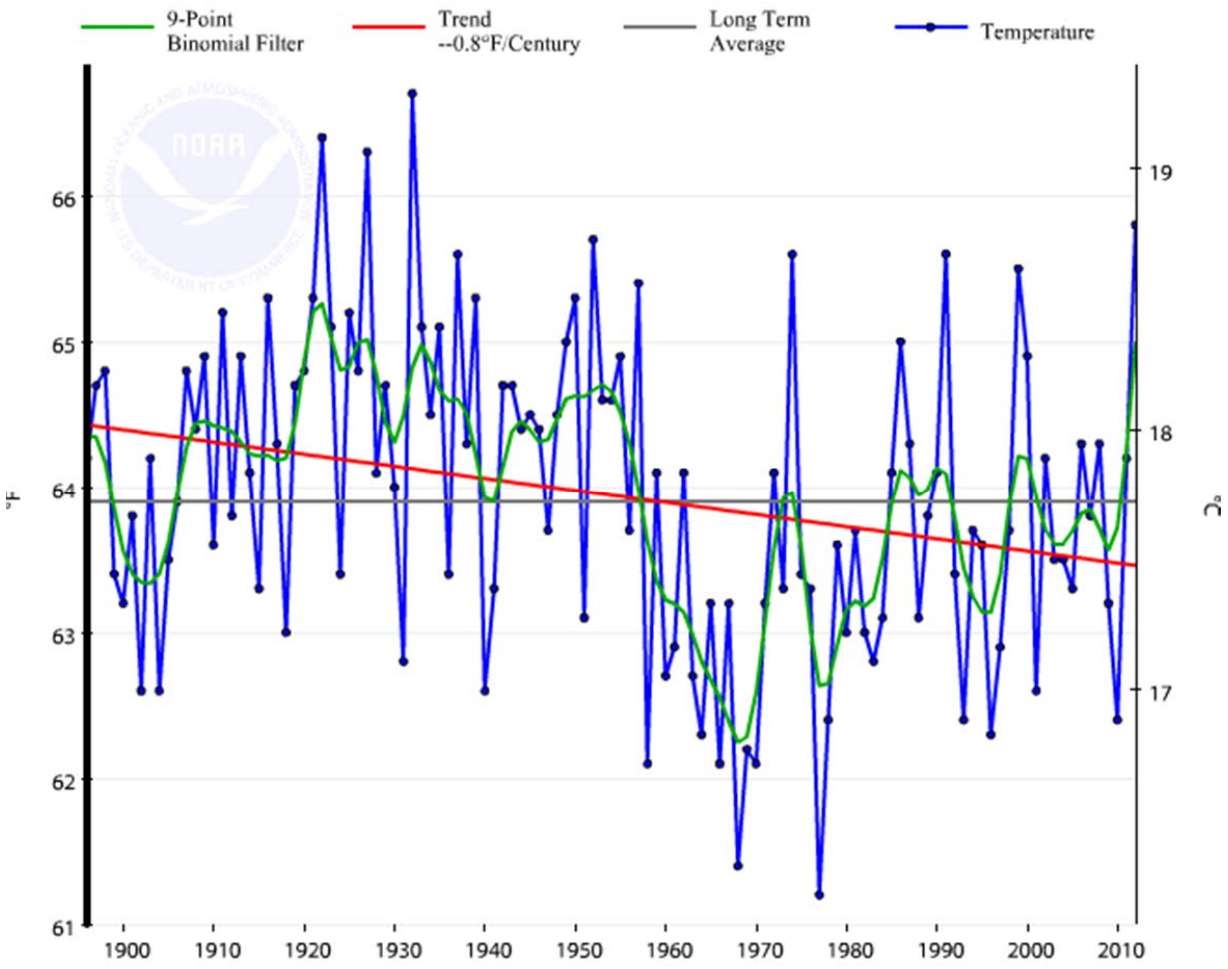

Figure 1. Georgia Air Temperature with Trend in Last Century

(From NOAA Website)

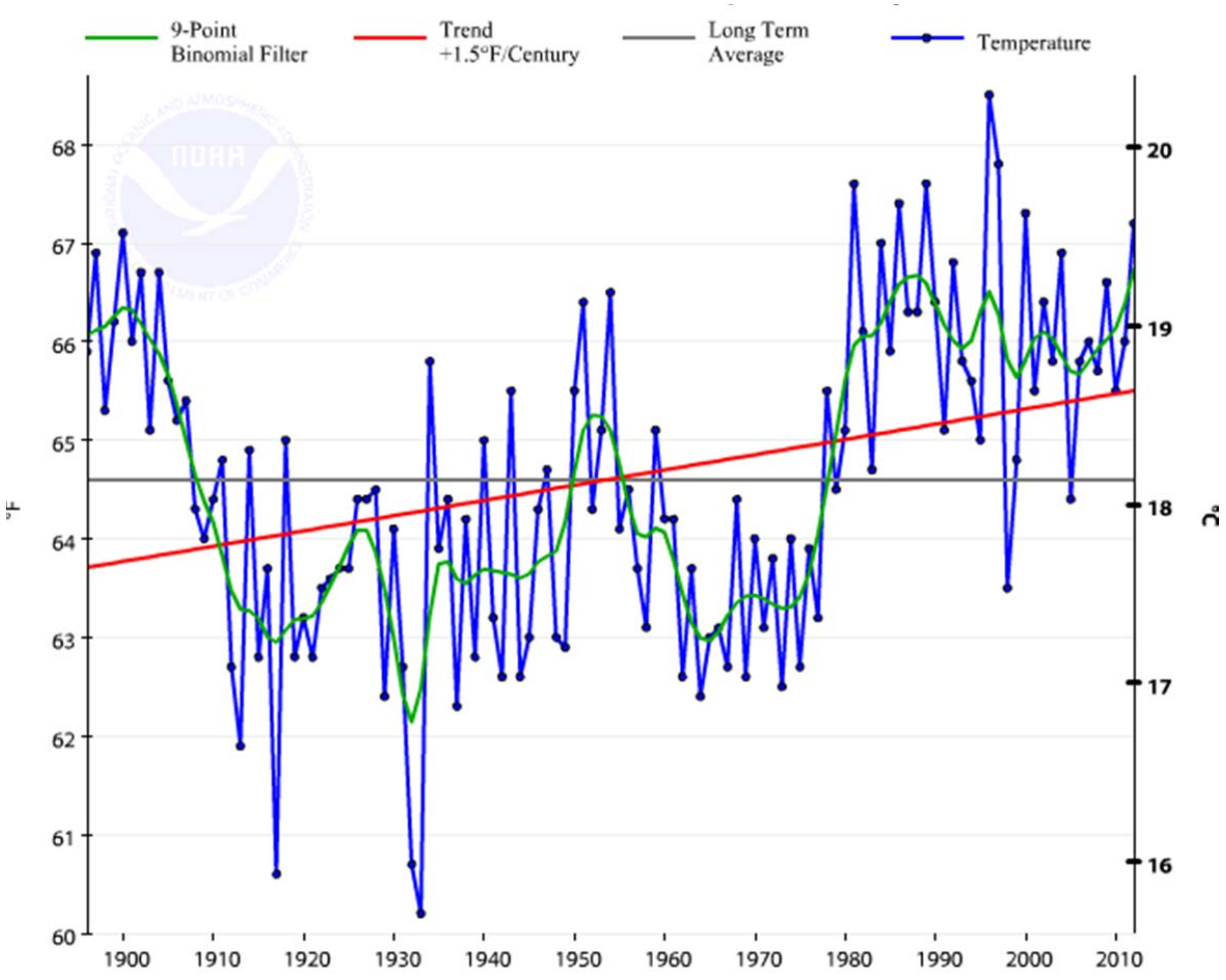

Figure 2. California Air Temperature with Trend in Last Century

(From NOAA Website)

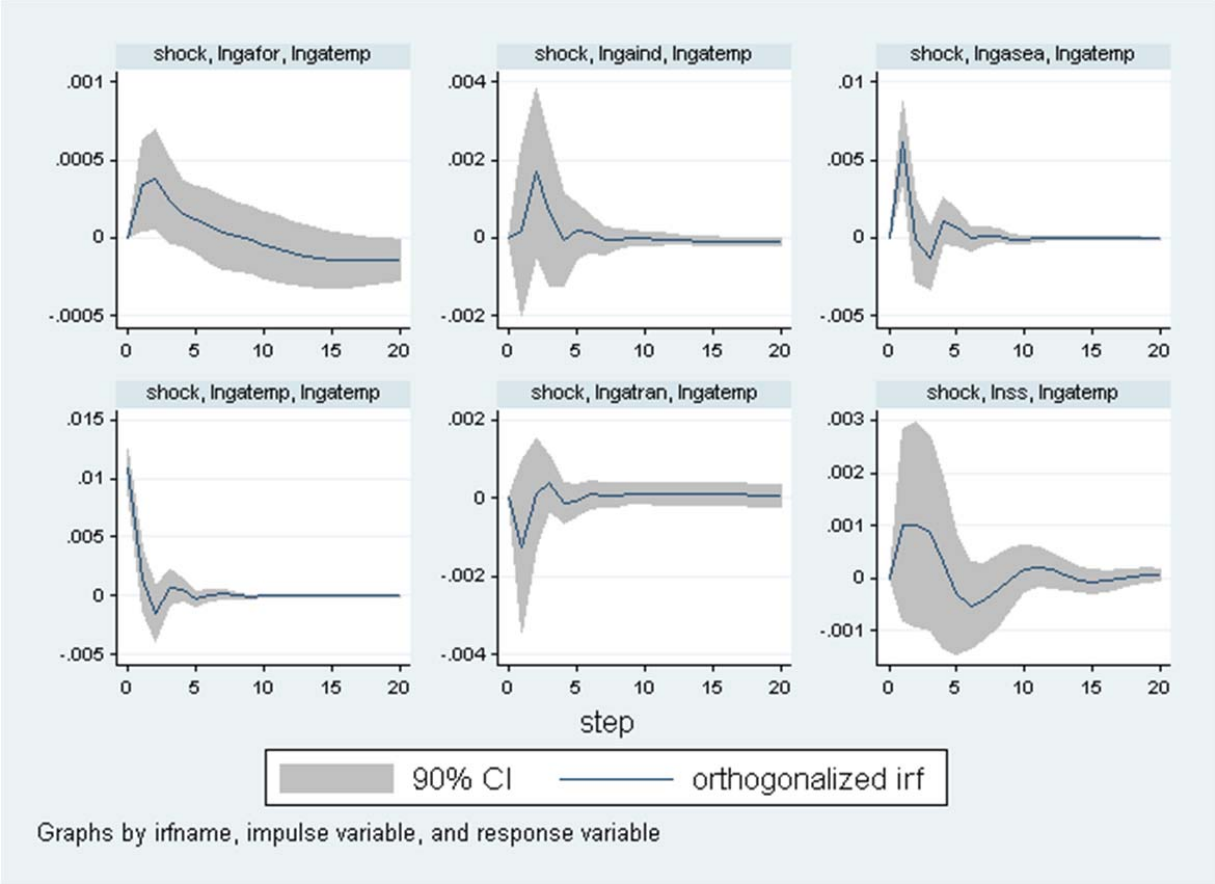

Figure 3. Impulse Response of Air Temperature to Shocks by Other Variables with 90% Confidence Band, Georgia

(The corresponding variables are, from top-left:

First row: forest area, petroleum consumption in industry sector, sea temperature;

Second row: air temperature, petroleum consumption in transportation sector, sun spot number.

And all data is in logarithm term.)

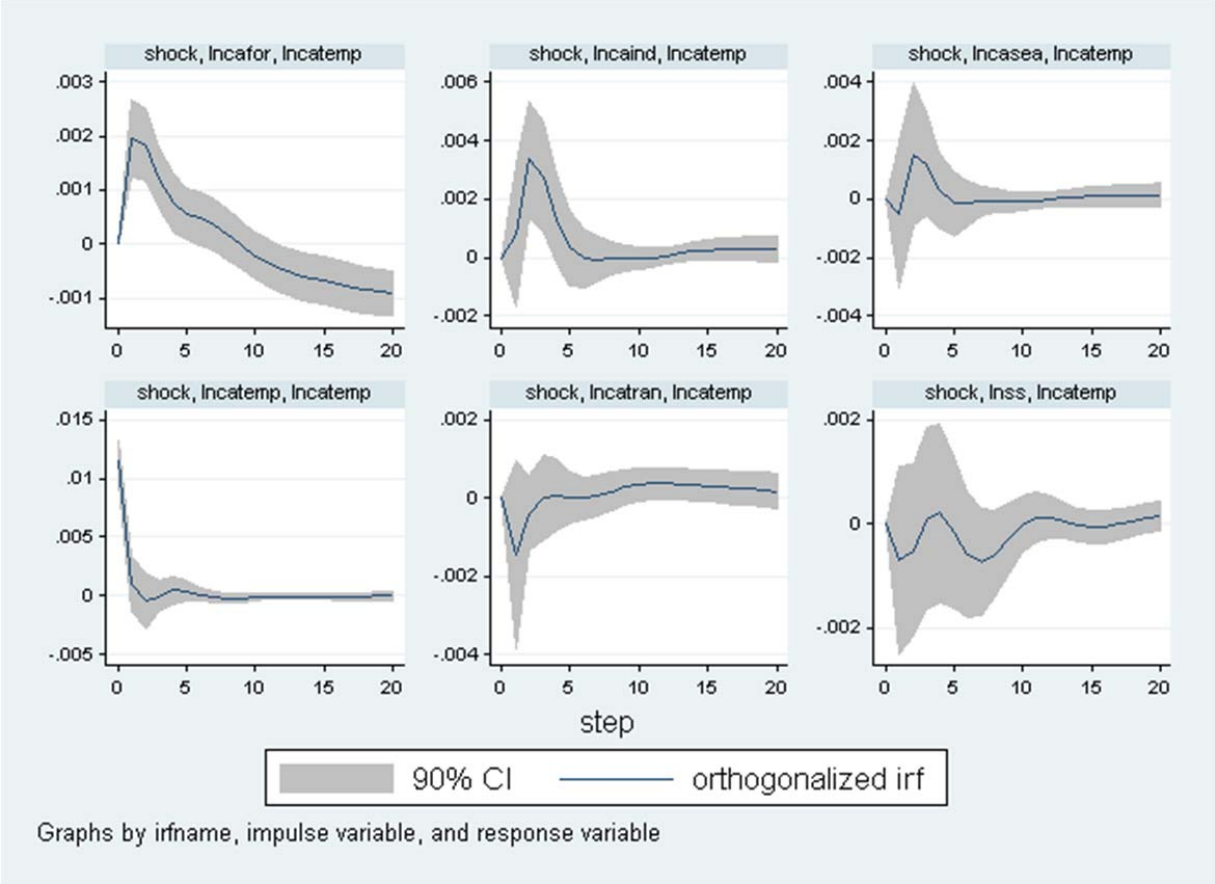

Figure 4. Impulse Response of Air Temperature to Shocks by Other Variables with 90% Confidence Band, California

(The corresponding variables are, from top-left:

First row: forest area, petroleum consumption in industry sector, sea temperature;

Second row: air temperature, petroleum consumption in transportation sector, sun spot number.

And all data is in logarithm term.)

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