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Spatial and Temporal Patterns of Temperature Change in Southeast Asia and Australia

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Abstract

In this study, we focus on surface temperature variation involving correlation in both time and space in Southeast Asia and Australia from 1973 to 2008. The area comprised 54 regions of 10^o by 10^o grid-boxes in latitudes 35°S to 25°N and longitudes 65°E to 160°E. The data were filtered with a second order autoregressive process to remove autocorrelations between temperature lags. Factor analysis was then used to account for spatial correlation between grid-boxes yielding six contiguous geographic regions. A fit of trend of each region by simple linear model showed that temperature averages in these six regions have increased gradually, ranging from 0.091 to 0.240^oC per decade.

Keywords: Southeast Asia, climate change, time series analysis, spatial correlation, autocorrelations, factor analysis

1. Introduction

The climate over a period involves the averages of appropriate components of the weather over that period, together with the statistical variations of those system components (Houghton et al.1990).Hughes et al. (2006) studied the variations in the minimum/maximum temperatures of the Antarctic region using a multiple regression model with non-Gaussian correlated errors and linear auto-regressive moving average (ARMA) models with innovations. Griffiths et al. (2005) investigated extreme temperature changes in the Asia-Pacific region over the period 1961-2003, covering latitudes 46°N - 47°S and longitudes 80°E - 120°W. This study focused on the relationship between mean and extreme temperature in the Asia-Pacific region. Trends and relationships were calculated using linear regression and Pearson correlation analysis.

Climate change in Southeast Asia is expected to lead to significant variations in precipitation patterns. Climate change also has occurred at a regional level; for example, a broad range of climatological and geographic features exist within the Asia/Pacific region. All of India and Pakistan as well as much of western China is arid or semi-arid, and this sub region has warmed by approximately 0.1- 0.2^oC per decade over the past 100 years (Preston et al. 2006). Southeast Asia is characterized by tropical rainforest and monsoon climates with high and constant rainfall (Cruz et al. 2007), and the upward trend of winter mean temperatures over 1954-2001 in the eastern region of Southeast Asia is 0.34°C per decade (Gong & Ho 2004).

Subsurface temperatures in four cities have been evaluated (Taniguchi et al. 2007).using nonlinearity to estimate the effects of surface warming due to urbanization and global warming, as well as the developmental stage of each city. Average surface temperature profiles in four Asian cities were compared. The magnitude of surface warming has been largest in Tokyo (2.8°C), followed by Seoul (2.5°C), Osaka (2.2°C), and Bangkok (1.8°C).

In Australia, trends in annual frequencies of extreme temperature events were examined, the result shows that the frequency of warm events has generally increased over at least the 1957 to 1996 period, whist the number of cool extremes has decreased (Collins et al.2000).

Temperature change in any large area is complex and varies considerably in both time and spatial correlation.Various statistical analyses have been used to model patterns of temperature change. For instance, Anisimov et al. (2007) investigated changes in air temperature in Russia. The spatial homogeneity of air temperature anomalies within each region were assessed through coefficients of correlation between the regionally averaged temperature time series and series at each station of this region, over the periods 1900-49 and 1950-2004. Portmanna RW et al.(2009) found that spatial variations in US temperature trends are linked to the hydrologic cycle. This study presents unique information on the seasonal and latitudinal structure of the linkage.Furthermore, sea surface temperatures of the North Atlantic Ocean during 1973-89 and 1990-2008 were described using auto-regression models, multivariate linear regression, factor analysis and spline linear models in conjunction with spatial correlation methods (McNeil & Chooprateep 2013). The temperatures in three regions which were identified by factor analysis were found to increase by approximately 0.13 ℃ per decade in the first period and slightly over 0.40 ℃ per decade in the second period.

The aim of this study is to investigate the trends and patterns in temperatures of a large specific region of Southeast Asia and Australia from 1973 to 2008. The selected region includes both land and sea, and temperature profiles of adjacent locations are correlated. Time series analyses use a simple linear model.

2. Methodology

The data were monthly temperatures in Southeast Asia and Australia for 5^o by 5^o latitude-longitude grid-boxes on the earth's surface were obtained from the Climate Research Unit (CRU, 2009), and described in detail by Brohan et al.(2006).The data from 1973 to 2008 were design of 10^o by 10^o grid-boxes using the average temperature.The data in the study area are located in latitude 35^{o}S to 25^{o}N and longitude 65^{o}E to 160^{o}E, and composed of Southeast Asian countries and Australia as shown in Figure 1.

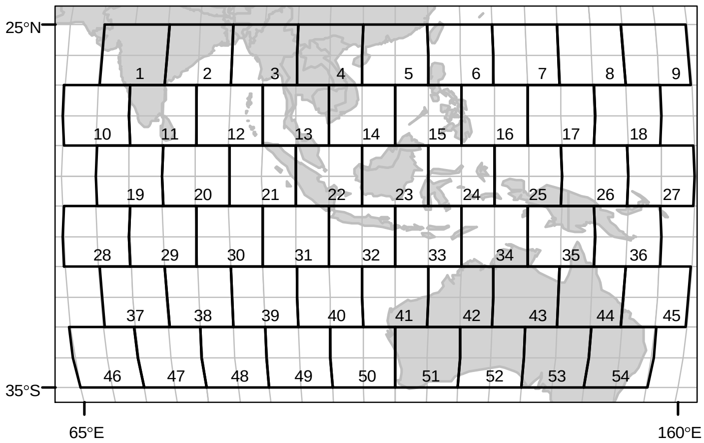

Figure 1. The study area

The data consist of 432 monthly temperatures and 54 grid-boxes. For each grid-box, temperatures were seasonally adjusted, seasonal variation was removed by subtracting the monthly average and then adding back the overall mean temperature. Simple linear model was used to fit these seasonally-adjusted temperatures (Figure 2), the model in this period takes the form

$$y_{it} = b_{0i} + b_{1i}\, d_t . \quad , \tag{1}$$

where y_{it} denotes the seasonally-adjusted temperature in grid-box i for month t and d_t denotes the time elapsed in decades since 1973, centred at the middle of the period, that is, $d_t = (t - n/2)/120$ for a period of n months,$b_{0i}$is the average temperature in grid-box i over the period, and b_{1i} is the estimated rate of increase in temperature per decade.

Time series data were considered, autoregressive (AR) models were used to account for the autocorrelations among the residuals from the fitted models. The average monthly temperature (y_{it}) in each grid-box was removed autocorrelations (AR) at lags 1 and 2 months and coefficients a_1 and a_2 are the estimated parameters of the model. The residuals (Z_{it}) from a second order AR model take the form (Chatfield 1996)

$$Z_{it} = y_{it} - a_1 y_{i,t-1} - a_2 y_{i,t-2} \quad , \tag{2}$$

Since there are six different sides of correlations in each box thus taking account of correlations. Factor analysis (Mardia et al. 1980) was applied to identify correlations between the filtered monthly temperatures in the 54 grid-boxes of each period. The factor model formulation with p factors, takes the form

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$$f_{ij} = \mu_j + \sum_{k=1}^{p} \lambda_j^{(k)} \emptyset^{(k)} \quad , \tag{3}$$

where f_{ij} are adjusted temperatures in month *i* and grid-box *j*, μ_j is the mean temperature of variables in grid-box *j*, $\lambda_j^{(k)}$ are the factor loadings at grid-box *j* on the k^{th} factor and $\emptyset^{(k)}$ are the common factors. All data analysis and graphical displays were carried out using R (R Developement Core Team, 2009).

3. Results

Separate linear models were fitted to the seasonally adjusted temperatures for each of the 54 grid-boxes of the study region. Figure 2 shows the temperature trends with fitted lines in each grid-box have increased over the 36-year-period.

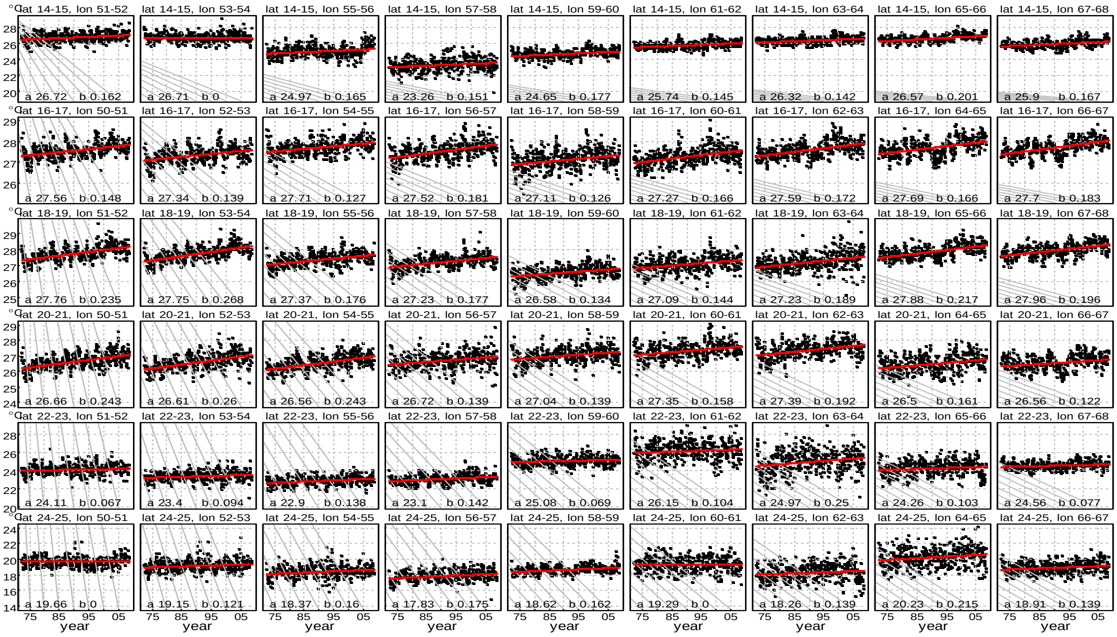

Figure 2. Temperature trends with fitted lines in 54 grid-boxes

The ACF plots in figure 4 show that all autocorrelations. To account for these significant autocorrelations, an autoregressive process of order two was fitted to the residuals from the linear regression model. The correlations in residuals from this fitted model are assumed to be stationary. Autocorrelations were accounted; an autoregressive process of order two was fitted to the residuals from the linear regression model. Figure 3 shows Autocorrelation function plot of the first grid-box is in left. The autocorrelations were removed from the filtering as shown in the right.

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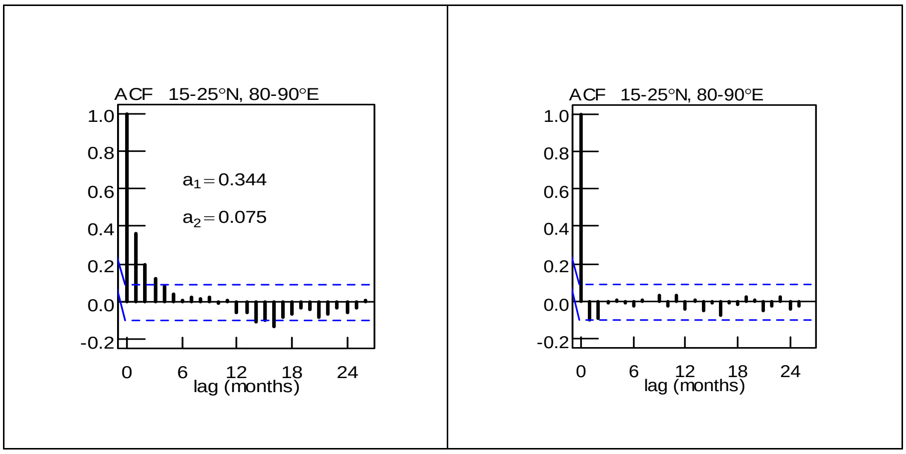

Figure 3. Autocorrelation function plots

After filtering, the factor analysis was applied to cluster 54 grid-box regions into six groups with different climate change patterns. In this case the variables are the filtered monthly temperatures within grid-boxes and the occasions are months. The correlation matrix is shown as a bubble plot, ordered by 6 factors in Figure 4. Of the 54 grid-boxes, 46 could be classified by factor analysis and combined into 6 factors (regions), which are displayed in Figure 5.

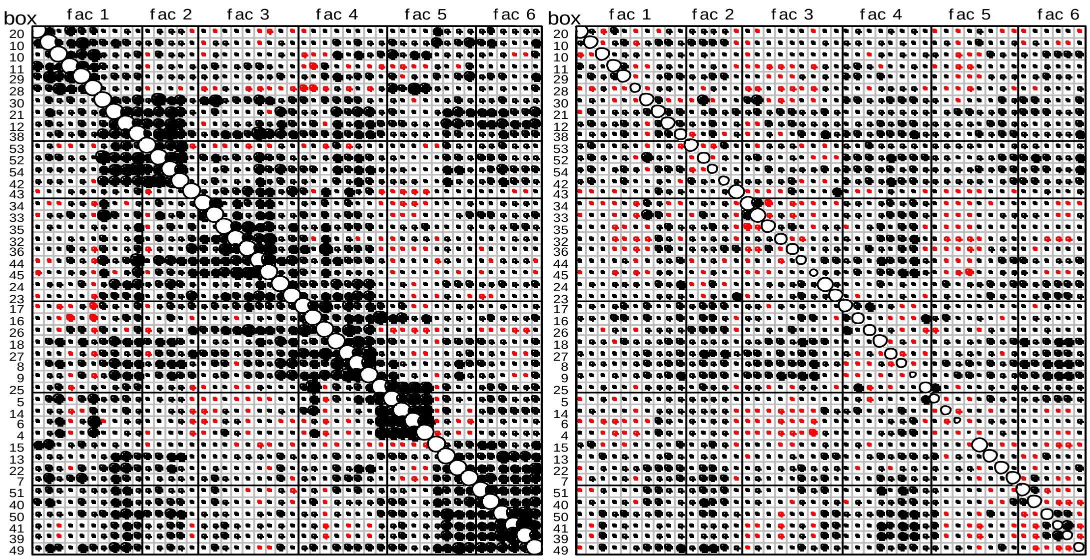

Figure 4. Bubble plots of correlations between filtered monthly temperatures in grid-boxes before (left) and after (right) fitting the factor model.

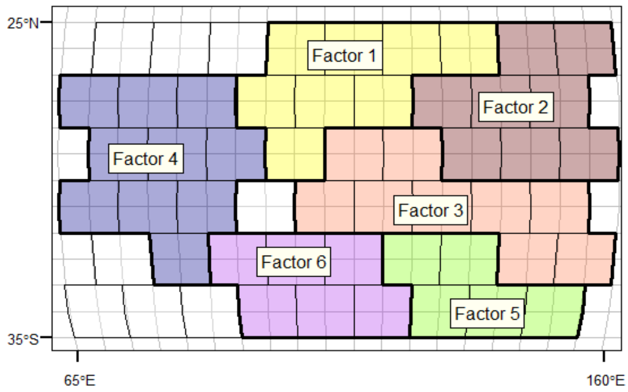

Figure 5. Adjacent grid-boxes were combined into six regions

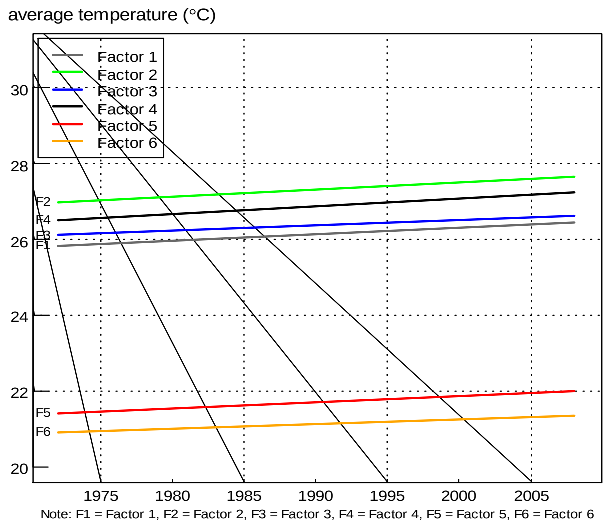

Figure 6. Six patterns of temperature change

Figure 6 shows that the temperatures increased for each factor, with increases ranging from 0.091 to 0.240°C per decade. Temperature increases are based on the linear regression model. The highest increase was in Factor 1 (Southern China, Vietnam, Cambodia, Thai, Laos, Malaysia, Singapore, Philippines) with 95% confidence interval 0.168±0.023°C per decade and the lowest increase was in Factor 6 (the West part of Australia) with 95% confidence interval 0.121±0.030°C per decade.

4. Discussion and Conclusions

This research analyses average monthly temperatures of a thirty-six-year period of the South-East Asia and Australia region, covering latitudes 35° S to 25°N and longitudes 75°E to 160°E. Various statistical methods were used including simple linear model, multivariate linear regression model and factor analysis. The linear model was fitted to the seasonally adjusted temperatures using data collected from fifty four of 10° by 10° grid-boxes. The temperatures were filtered by removing the autocorrelation using an AR(2) process. Because of spatial correlation in this study, factor analysis was used to classify filtered monthly temperatures in grid-boxes into six regions. Finally, a fit of trend of each region by simple linear model, which showed that temperatures have average increased gradually during 1973-2008. Future studies could be extended from this area to other areas.

5. Acknowledgements

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References

Anisimov, O.A., Lobanov, V.A. & Reneva, S.A. (2007), "Analysis of changes in air temperature in Russia and Empirical forecast for the first quarter of the 21st century." *Russian Meteorology and Hydrology.* **32**(10): 620-626.

Brohan, P., Kennedy, J.J., Harris, I., Tett, S.F.B. & Jones, P.D. (2006), "Uncertainty estimates in regional and global observed temperature changes: A new data set from 1850", *J Geophysical Research 111, D12106.*

Chatfield, C. (1996) "The Analysis of Time Series", *Chapman & Hall, Melbourne.*

Collins D.A., Della-Marta, P.M., Plummer N & Trewin, B.C. (2000),"Trends in annual frequencies of extreme temperature events in Australia*", Australian Meteorology Magazine*.**49**: 277-292.

CRU. 2009. Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, *UK. http://www.cru.uea.ac.uk/cru/data/temperature.* Accessed April 1,(2010)

Cruz, R.V., Harasawa, H., Lal, M., Wu S., Anokhin, Y., Punsalmaa B , Honda, Y., Jafari, M., Li, C & Ninh N.H. (2007), "Climate Change 2007: The Scientific Basis. Contribution of working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", *Cambridge University Press: Cambridge*

Gong, D.Y & Ho,C.H. (2004), "Intra-Seasonal Variability of Wintertime Temperature Over East Asia" ,*J. Climatol* **24**: 131-144

Griffiths, G.M.,Chambers, L.E., Haylock, M.R., Manton, M.J., Nicholls, N., Baek, H.J., Choi, Y., Della-Marta, P.M., Gosai, A., Iga, N., Lata, R., Laurent, V., Maitrepierre, L., Nakamigawa, H., Ouprasitwong, N., Solofa, D.,Tahani, L., Thuy, D.T., Tibig, L.,Trewin, B., Vediapan, K. & Zhai,P. (2005), "Change in mean temperature as a predictor of extreme temperature change in the Asia-Pacific region", *J.Climatol*. **25**: 1301-1330.

Houghton JT, Jenkins, G.L., Ephraums, J.J. (1990), "Climate Change: The IPCC Scientific Assessment", *Cambridge University Press:* Cambridge

Hughes, G.L., Rao, S.S. & Rao,T.S. (2006), "Statistical analysis and time-series models for minimum/maximum temperatures in the Antarctic Peninsula", *The royal society,* doi:**10**.1098/rspa.2006.1766.

McNeil, N. & Chooprateep, S. (2013), "Modelling sea surface temperatures of the North Atlantic Ocean", *Theor Appl Climatol DOI* **10**.1007/s00704-013-0930-0

Mardia, K.V., Kent, J.T. & Bibby, J.M. (1980), "Multivariate Analysis, Academic Press Inc",*(London) Ltd.*

Portmann, R.W., Solomon, S. & Hegerl, G.C. (2009), "Spatial and seasonal patterns in climate change, temperatures, and precipitation across the United States", *National Oceanic and Atmospheric Administration, Princeton, NJ.*

Preston, B.L., Suppiah, R., Macadam, I. & Bathol, J. (2006), "Climate Change in the Asia Pacific Region. A Consultancy Report Prepared for the Climate Change and Development", *Roundtable CSIRO Marine and Atmospheric Research*