

Land Surface Temperature Anomalies in Central Asia: A Regional Analysis - 2001-2014

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Abstract

This study analyzes day and night times mean monthly anomalies of Land Surface Temperatures in Central Asia Region from 2001 to 2014 based on the raster datasets derived from TERRA-MODIS observations. The results shows that larger proportion of the total area experienced fluctuations between -10 degrees and 5 degrees Celsius in both day and night times temperatures during the winter months. Most of the summer months show frequent annual swaps of these anomalies but the number of years recording higher temperatures in larger proportion of the region are more than those recording lower temperatures. The analysis of overall maximum, minimum and mean day and night times temperature anomalies shows that most of the areas experienced extreme anomalies up to minus 12 degrees and plus 12 degrees at one or the other time. The composite results show only a few areas having continuously high anomalies up to 2.5 degrees whereas most of the areas experienced temperature decrease up to -2.5 degree Celsius.

1. Introduction

Central Asia region has a total area of about 4 million KM² shared by five countries (Figure 3) namely Kazakhstan (2,717,300 KM², 68%), Kyrgyzstan (199,951 KM², 5%), Tajikistan (143,100 KM², 4%), Turkmenistan (488,100 KM², 12%) and Uzbekistan (447,100 KM², 11%). Most of the areas in Kazakhstan, Uzbekistan and Turkmenistan are nearly flat or have small undulations and very small areas have hills and Mountains. Contrary to this, Kyrgyzstan and Tajikistan are largely mountainous countries and altitude of about half of the area of Tajikistan is more than 3000 meters. The regional altitude ranges between minus 81 meters at Vpadina Akchanaya depression in Turkmenistan to 7495 meters Somoni Peak in Tajikistan. Very large part of the region has scarce vegetation (Figure 3) and the predominant climatic conditions of Central Asia have been defined as desert and continental type, characterized by very cold winters are severely hot summers (Indoitu et al., 2012 and Orlovsky et al., 2013). Various parts of the region experience winter temperatures below minus 20° Celsius and summer temperature above 40° Celsius (Peel et al., 2007). The Distributions of snowfall and rainfall also vary widely across the region (vonWehrden et al., 2010 and ZEN, 2009). Several manifestations of climatic changes and their multi-dimensional effects on environment and society have been observed in Central Asia during the last decades and the stake

holder countries have pledged to work together for mitigating the severer effects (WB, 2014b). Observing the fast changing climatic conditions and human response to these, it has been stated that "... average temperature increases directly affect human health and life, as there is no chance to adapt and re-adjust to fast changes in such a short time. May be only the simplest forms of life in the animal kingdom (protozoa) or very rich people are capable of doing this" (GEF, 2008). Some researchers conclude if the current trends of climatic changes in Kazakhstan continue, which are expected, these will have serious impacts on the climate-dependent agricultural and transhumance activities further affecting human health and wellbeing (ZEN, 2009). The impacts in Kyrgyzstan are reflecting through hotter summers, disappearing rivers and increasing incidence of sick animals (Igoe, 2012). The concerns in Tajikistan have been expressed beyond the above mentioned factors and the discussions include worries about the future of economic and social development (UNDP, 2012). Similar observations have been made and the concerns have been expressed about Turkmenistan and Uzbekistan as well (WB, 2013 and 2014a). Overall, the changes in temperatures seem to be the major causal factor of other climatic fluctuations affecting a range of environmental, socio-economic and developmental processes. This study analyzes mean monthly day

time and night time Land Surface Temperature Anomalies in Central Asian region from 2001 to 2014. The conditions of Land Surface Temperature influence a wide variety of climatic, hydrological and ecological processes as well as land based economic activities. Land Surface Temperature, being a key parameter in the physics of land surface processes, is considered as a good indicator for understanding the energy balance at Earth's surface (NEO). This provides composite results of interactions between surface and atmosphere as well as insights into the energy fluxes between these two.

2. Data and Methods

This study is based on 2 types of observations derived from TERRA-MODIS datasets available for free and open access on NASA Earth Observations (NEO: <http://neo.sci.gsfc.nasa.gov>) data portal. The types of used datasets are following:

- Average Monthly Day Time Land Surface Temperature Anomalies from January 2001 to December 2014.
- Average Monthly Night Time Land Surface Temperature Anomalies from January 2001 to December 2014.
- Ancillary data of snowfall and rainfall has been used to explain the extreme anomalies observed in selected months of a few years.

These are global level raster datasets available in GeoTIFF format containing pixels of 0.1 degree spatial resolution, i.e. about 11 Kilometres on ground. This resolution is acceptable for a regional level analysis of Central Asia enveloping total area of about 4 million KM². The datasets represent temperature anomalies of the top 1 millimeter layer of the land surface for each calendar month compared to the average conditions of that month during 2001 and 2010. The pixel values range from 1 to 255 where 255 means 'No Data' and the values from 1 to 254 represent Land Surface Temperature anomalies from minus 12 degrees to plus 12 degrees Celsius. The values are shown with the help of a graduated color ramp which makes it difficult to identify the critical boundaries of Land Surface Temperature Anomalies.

ESRI ArcGIS Desktop version 10.3 has been used for processing and analyzing the datasets. The shape files containing the boundaries of all the 5 Central Asian countries have been merged for obtaining the boundary of Central Asia region and used for extracting the area of interest from the global

datasets. The required datasets were classified as per the schema given in table 1. The pixel values of each class and the corresponding temperature values have been calculated and presented according to the following procedures:

- The highest pixel value 254 containing valid data of temperature anomaly was divided by 48, i.e. double the number of 24 temperature degrees from minus 12 to plus 12, for obtaining the pixel values representing each 0.5 degree temperature anomaly and the resultant value is 5.291666.
- This value (5.291666) was multiplied by the number of degrees included in each class for obtaining the pixel value falling in the corresponding classes and rounded-off to the nearest whole numbers because the pixel values are in integer format.
- The datasets were classified using 'Reclassify' tool in ArcGIS and the number of pixels in each class of each dataset were tabulated using 'Zonal Histogram' tool. The tables of each month from 2001 to 2014 were combined with the corresponding tables and used for preparing Radar Diagrams in MS Excel (Figures 1 and 2).
- The overall spatial pattern of Maximum, Minimum and Mean Land Surface Temperature Anomalies during 2001-2014 from all the 168 day time and 168 night time datasets was obtained separately using 'Cell Statistics' tool in ArcGIS. The resultant 6 datasets were classified by reducing the class interval shown in Table 1 for visualizing more details (Figure 3).

Table 1: Classification Scheme

Pixel Value	Mean Monthly Temperature Anomaly (°C)
0 - 21	-12 to -10
21 - 74	-10 to -5
74 - 127	-5 to 0
127 - 180	0 to 5
180 - 233	5 to 10
233 - 254	10 to 12
255	No Data

3. Results and Discussion

3.1 Day Time Land Surface Temperature Anomalies

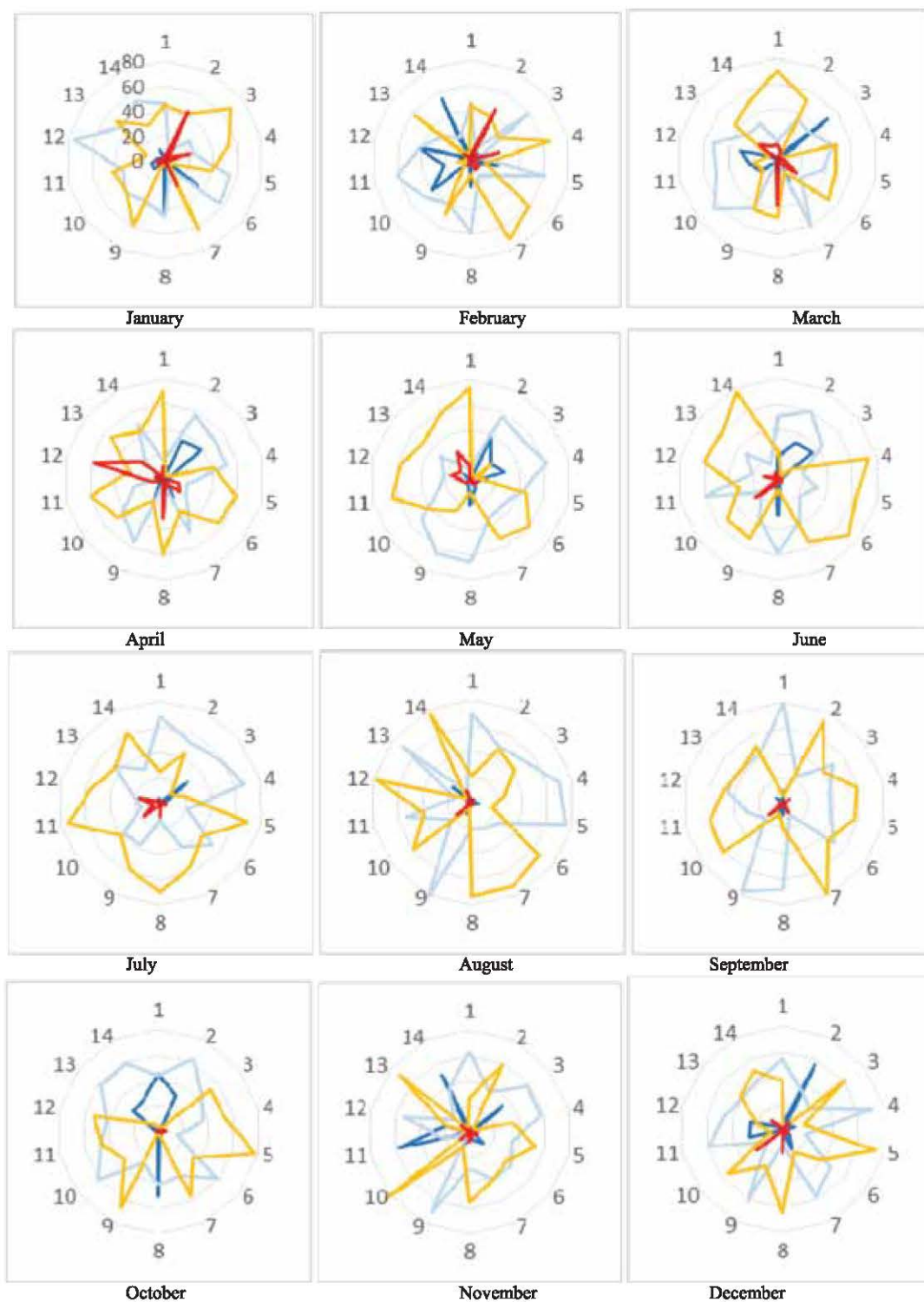
Significant fluctuations are observed in the day time Land Surface Temperature Anomalies in the months of January, February, March, October, November and December from 2001 to 2014 (Figure 1). More than 60 percent of the total area of Central Asia falls in the category of 0 to 5 degrees Celsius in some years whereas similar proportion of the area falls in

the category of -10 to -5 degrees Celsius during the other years. Some areas are also seen in the categories of 5 to 10 and -12 to -10 degrees quite frequently but their proportion in the whole area is quite small. The month of May shows cooling and warming phases of 2 to 3 years alternatively from 2002 to 2010 and continuous warming up to 5 degrees Celsius from 2011 onwards. In August, a cooling up to -5 degrees Celsius is observed in larger areas from 2001 to 2005 and a warming up to 5 degrees Celsius between 2006 and 2008. Thereafter, the cooling and warming in this month is observed in alternative years till 2014. Except for 2009, about 60 percent area shows warming up to 5 degrees Celsius in the month of April from 2008 to 2014 whereas it had increased up to 10 degree in 2012. Similarly, the warming in September between 2002 and 2014 was disrupted only in 2008 and 2009 but 40 to 60 percent area experienced up to 5 degree rise in all other years. July is the only month showing two clear cooling and warming phases. The cooling up to -5 degrees is observed from 2001 to 2004 and a continuous warming up to 5 degrees in 40 to 70 percent area since 2005. The overall observations of the day time Land Surface Temperature Anomalies from 2001 to 2014 show that the winter months experience significant fluctuation which seems to have a relationship with the fluctuations in snow covered areas during these months. The highest day time temperature anomaly of up to 10 degrees in January is seen in 2002 and one of the lowest proportion of snow covered area is also observed in the same month. Similar relationship is observed during April 2012. The Spring, Summer and Autumn months show a warming trend in larger number of years. The fluctuations in the month of August may be attributed due to the higher rainfall being received during this month. However, further investigations are required for detailed analysis. Most of the areas recording highest maximum day time Land Surface Temperature Anomalies between 10 and 12 degrees Celsius are located in the central, western, northern and northeastern parts of Kazakhstan, western parts of Uzbekistan and high mountain parts of Kyrgyzstan (Figure 3). The lowest maximum day time Land Surface Temperature Anomalies between 5 and 7.5 degrees are observed in southwestern, southern and southeastern parts of Kazakhstan, southern Uzbekistan, most of the areas in Turkmenistan as well as lower altitude areas in Kyrgyzstan and Tajikistan. The areas experiencing highest minimum day time Land Surface Temperature Anomalies between -12 and -10 degrees are distributed all over the region, though the density of such areas in central and northern

parts of Kazakhstan as well as in southern Turkmenistan is scanty than in other parts. Only some higher areas of Kyrgyzstan and Tajikistan recorded highest minimum day time Land Surface Temperature Anomalies between -7.5 and -5 degrees Celsius.

3.2 Night Time Land Surface Temperature Anomalies

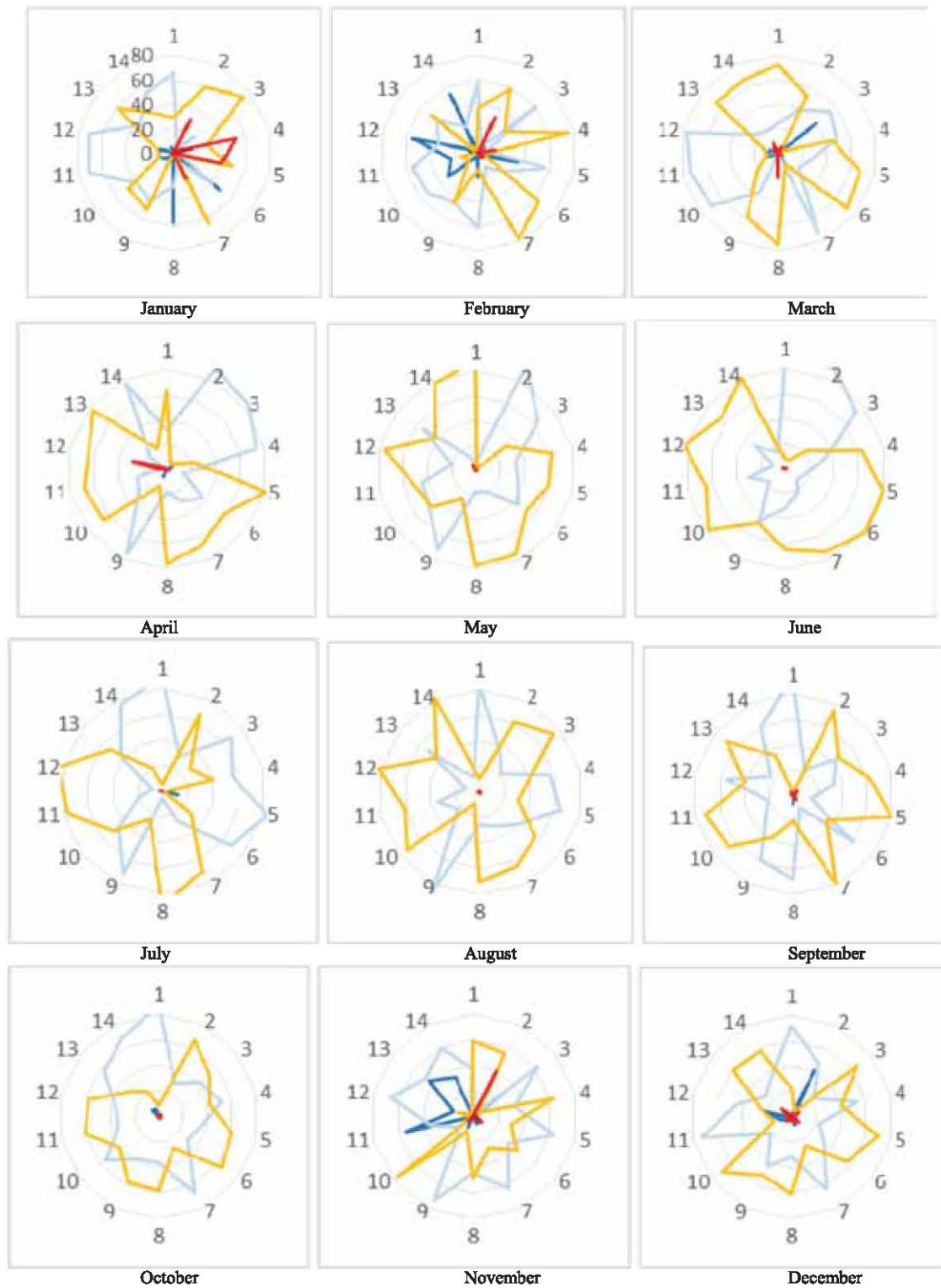
Similar to day time, the night time Land Surface Temperature Anomalies show frequent fluctuations in the months of January, February and November but the Months of March and December are more stable as compared to the day time anomalies (Figure 2). A warming up to 5 degrees Celsius and a cooling up to -5 degrees is observed irregularly during intermittent years in the months of July, August, September and October. However, the percentage of area under each category in each month is between 60 and 80 percent during most of the years which is much higher as compared to the day time Anomalies. Recording a break in 2009, the month of April shows a continuous trend of night time temperature anomalies up to 5 degrees in larger part of the region from 2005 to 2012. This trend in the month of May is observed from 2004 to 2014 with another minor break in 2013. June is the only month showing significant cooling up to -5 degrees in night time temperatures from 2001 to 2003 and a continuous warming up to 5 degrees in 60 and 80 percent area since 2004. The only exception is that the area under this category was about 50 percent in 2009. A comparison of the day time and night time Land Surface Temperature Anomalies show a trend toward rising temperatures in larger areas of Central Asia especially during the Spring and Summer months. However, 2009 was an exceptional year when larger proportion of the total area experienced an anomaly up to -5 degrees Celsius during several months. The Highest maximum night time Land Surface Temperature Anomalies between 10 and 12 degrees Celsius are concentrated around the eastern, northern and western areas of Aral Sea as well as around the eastern parts of Balkash Lake in Kazakhstan (Figure 3). Most of the areas in Kazakhstan, Uzbekistan and Turkmenistan show night time temperature anomalies between 5 and 10 degrees. Larger parts of Kyrgyzstan and Tajikistan recorded these anomalies between 2.5 and 5 degrees. Most of the areas in Kazakhstan, Uzbekistan and Turkmenistan faced highest minimum night time Land Surface Temperature Anomalies between -12 and -7.5. This anomaly is recorded between -5 and zero degrees Celsius in larger parts of in Kyrgyzstan and Tajikistan.



The 4 concentric rings of the Radar Diagrams show percentage of area i.e. 20, 40, 60 and 80 percent. The numbers on the outermost ring mean 1 = 2001... 14 = 2014. The lines of different colors show percentage of area falling under various classes of Land Surface Temperature Anomaly.

— -12 to -10 — -10 to -5 — -5 to 0 — 0 to 5 — 5 to 10 — 10 to 12

Figure 1: Proportion of Total Area with Mean Monthly Day Time Temperature Anomalies - 2001-2014



The 4 concentric rings of the Radar Diagrams show percentage of area i.e. 20, 40, 60 and 80 percent. The numbers on the outermost ring mean 1 = 2001... 14 = 2014. The lines of different colors show percentage of area falling under various classes of Land Surface Temperature Anomaly

— -12 to -10 — -10 to -5 — -5 to 0 — 0 to 5 — 5 to 10 — 10 to 12

Figure 2: Proportion of Total Area with Mean Monthly Night Time Temperature Anomalies - 2001-2014

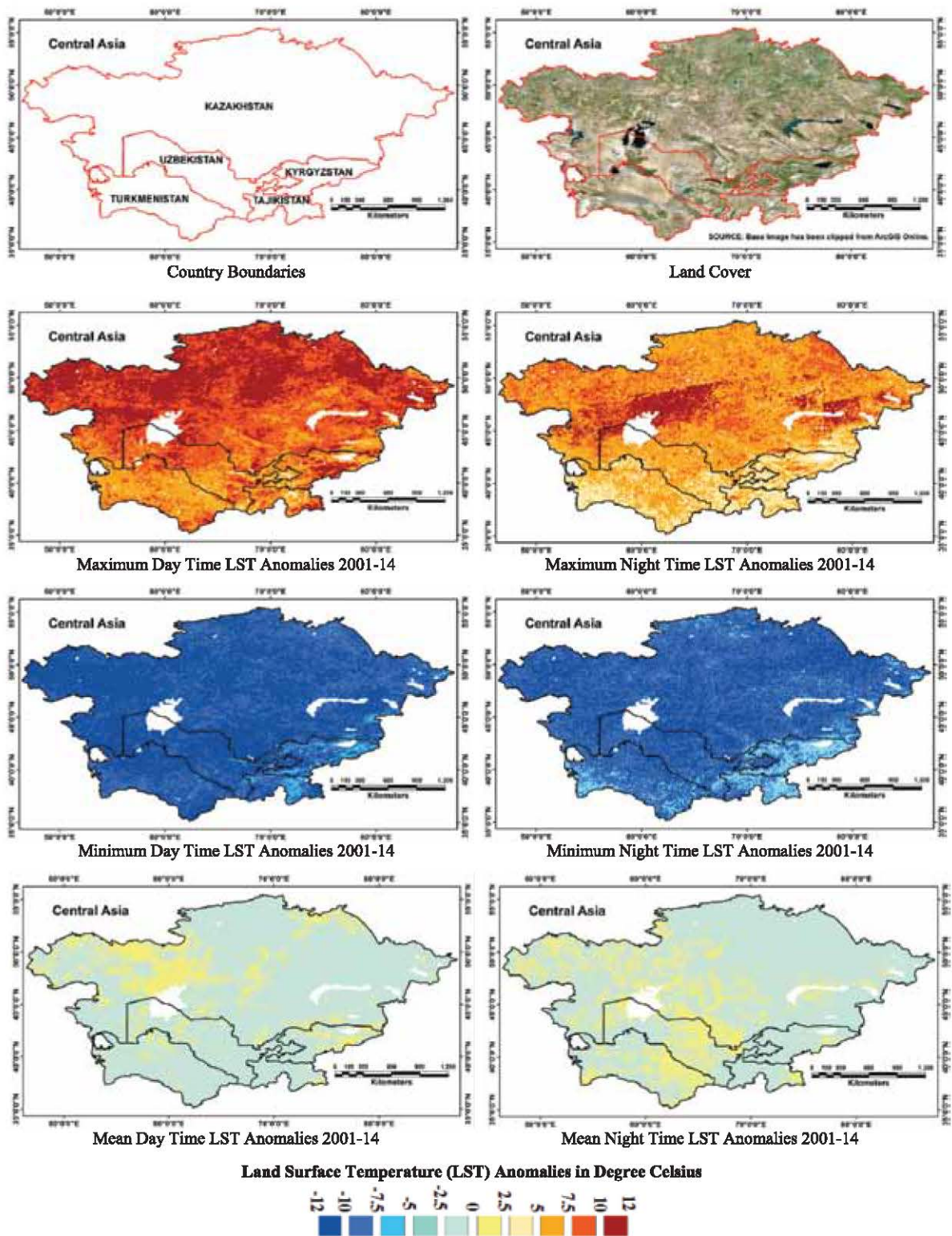


Figure 3: Central Asia: Maps Showing Different Aspects

6. Conclusions

The analyses of mean monthly day time and night time Land Surface Temperature Anomalies in Central Asia during the last 14 years period from 2001 to 2014 give varied results. Overall, the spring and summer months show a trend of warming and the winter months show significant fluctuations. The spatial pattern of maximum and minimum anomalies both for day and night temperatures show extreme values in most of the areas of Kazakhstan, Uzbekistan and Turkmenistan whereas the anomalies in Kyrgyzstan and Tajikistan are largely lower in all the cases as compared to the other 3 countries. The pattern of mean day time and mean night time Land Surface Temperature Anomalies (Figure 3) show a decrease between -2.5 and 0 degrees Celsius in most of the areas in Central Asia and only a small proportion of the total area shows an increase between 0 and 2.5 degrees Celsius. Although there are some differences in the pattern of both overall mean of day and night time Land Surface Temperature Anomalies but these show that the areas experiencing an increase in the temperatures are located largely in the western half of Kazakhstan, all over Uzbekistan and Turkmenistan. This pattern coincides with the pattern of sandy deserts in these countries which record high diurnal, seasonal and annual ranges of temperatures. On the other side, temperature increase is observed in higher rocky mountain areas of Kyrgyzstan and Tajikistan. This study concludes that irrespective of the fact that the extremes of high and low temperatures are observed in most of the areas at one or the other time but only a few areas are experiencing continuous warming and most of the areas are recording a decrease. It is also observed that the areas in northern latitudes and higher altitudes are experiencing higher temperature increase as compared to the southern latitude and lower altitude areas. This means formerly colder areas are becoming warmer which explains melting of glaciers in these areas. And this seems to be drawing major concerns because the retreat of glaciers is directly visible whereas several other aspects require measurements using special instruments and equipment over a considerable long period of time. It seems that the conclusions about the climatic changes in Central Asia are being drawn from the extreme weather conditions observed over short periods of time ignoring the time period required for discerning definite trend and direction of the changes. Thus, more detailed studies are required to fill this gap to help designing viable adaptation strategies and mitigating severer impacts of climatic changes on environment and

society many of whom say "Now it's better, it's good for us. The warmer weather is better than the cold. Apples and mulberries now grow in our village" (UNU, 2010).

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