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A study of the relationship among temperatures of surface features and its application in remote sensing study of Lut desert

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Abstract

Physical characteristics of different features in desert is a reflection of severe thermal and climatic conditions. In this paper, diurnal surface temperature patterns of important surface features in Lut Desert were studied and the relationship among different surfaces analyzed. Diurnal trend in surface temperature of surface types, marl, dark sand, light sand, salt-affected soil, soul at 10 cm depth, as well as dry and wet air temperature within 15 days were recorded in 2 hour intervals in the margin of Lut yardangs while correlations among these surface features and its significance level were investigated. The knowledge of diurnal temperature pattern and calculation of correlation among features can lead us to the understanding of the behavioral pattern and the trend of surfaces. The knowledge of behavioral pattern of correlation coefficients during different hours of the day provides the researchers the ability to produce optimal models of thermal characteristics and to predict them. Additionally, thermal data of different sensor systems along with their capability in the study of surface features in Lut Desert was evaluated. The results of thermal and inter-feature correlation analysis reveal a similar trend (at 8 AM and 4 PM) among various feature types. The correlation coefficient of different surfaces shows the highest value at 6 AM and the lowest at 8 PM. The correlation coefficient between sand and marl with grey sand and soil shows a non-linear trend at pre-noon hours while a linear and similar trend in the afternoon. Generally speaking, the correlation coefficient between surfaces at pre-noon hours as compared to afternoon hours is completely non-linear and does not reveal any specific pattern. It seems that TIR data acquired at 10 AM is the best choice in the study of Lut Desert and hence ETM+ and TM data can be used.

Keywords: Thermal Infrared Data; Land Surface Temperature; Physical and Thermal characteristics; Lut Desert; Surface features

1. Introduction

Temperature and its behavioral patterns are of great importance in biological systems (the growth of plants and animals); physical systems (destruction, erosion); as well as in chemical systems (Cryoclasty, evapotranspiration, especially in hot and dry climatic conditions) and therefore should be considered in the studies related to earth sciences (Norman et al., 1995).

Features and materials forming the surface of the earth absorb, reflect and transmit solar electromagnetic radiation. Meanwhile, short-wave solar radiation is absorbed and by heating the surface materials is omitted as long-wave radiation (Jensen, 2000). So, the main factor in surface temperature is the absorbed energy of solar radiation. Other factors which affect surface temperature are physical and thermal characteristics of surface features along with overall climatic conditions (Alijani, 1992). Thus, for on interpretation of temperature fluctuations of surface features such as soil and rocks, the above facts should be taken into account.

Soil is a complicated physical, chemical and

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biological feature. So it is logical to expect its diurnal thermal oscillation (Alavipanah, 2003). Surface temperature shows periodical changes in daily, monthly, seasonal and annual cycles (Alavipanah, 2006). In the study of LST, thermal characteristics of soil such as specific heat, thermal conductivity, and thermal inertia are very important and show temporal changes (Kaviani, 2001). Rocks and minerals always show lower specific heat and thermal conductivity than water and vegetation cover and hence show more daily temperature fluctuations. Inside the rocky and soil surfaces thermal conductivity has an outstanding role in transferring the incoming energy inwards. Surfaces characterized by higher thermal conductivity show a more thermal stability than those having less thermal conductivity. Also the heating of surfaces has an effect on the near-surface air temperature, as such up to the 120 cm of surface thermal fluctuation of surface and air is comparable. Soils with more thermal conductivity (mineral soils) have more effect in near surface air temperature while those with less thermal conductivity (Humus or spongi soil) don't affect air temperature extensively. Each type of soil in compressed and dense shape shows more conductivity than in its disjointed and porous state. The reason is that the thermal conductivity of soil mineral particles with 0.005 calorie is much higher than that of air and water. Soil types with layered and fragmented structure show more thermal conductivity than those with granulated structure. As a result the conductivity of mineral soils is more than that of organic soils. Clay, because of its (silicaaluminium) composition has more molecular water than quartzite minerals without moist particles. As a result moist soils show larger thermal stability than sandy soils. In salty soils the densification of in solution salts lessens evaporation and has an indirect effect on thermal balance of soil (Hami, 1980).

Diurnal fluctuations of soil surface temperature are affected by external factors, in addition to its internal characteristics. External factors increasing thermal fluctuations of soil types are: 1) intense sunshine 2) large surface albedo 3) soil surface dryness and 4) large thermal diffusion (Rafie, 1970). The duration of emission of absorbed energy is approximately twice that of energy absorption due to different emission intensities and because they occur in different regions of electromagnetic spectrum. This becomes soil resolvable using near sunset thermal data.

Soil of desert regions due to a lack of moisture and accumulation of heat in a near surface crust, has a high day-time and low night-time temperature (Kaviani, 2001), so that as the severity of dryness increases in a region, the role of physical and thermal charactreristics of forming materials in the control of temperature pattern becomes prominent. Although dry regions, due to such factors as sparse vegetation cover, scarcity of organic components, direct exposition to sunlight, etc. is an ideal environment for the study of thermal characteristics of surfaces, but soil is a complicated phenomena which its variations in color, texture, structure and forming minerals (quartz, silicates, calcites and iron oxides) has a considerable effect on thermal patterns of desert surfaces. In generally, soil temperature is dependant on the daytime incoming solar energy and the nigh-time outgoing energy through emission of long-wave radiation. The change in trend of soil temperature is more regular than that of air and follows a daily cycle. But the behavior of various desert surfaces, considering different thermal conditions, is diverse. On these lines, using proper equipments and methods for accurate assessment of different soil types can contribute to the correctness of temperature evaluation. The variation of temperature can always provide us with significant information about type and conditions of features. Thermal curves of soil, rock and water are totally different. Daytime soil temperature is higher than that of waters and its night-time temperature is lower. Surface temperatures of features and different colored materials are different. Quick temperature changes (sharp slope curves) occur near dawn and dusk. Some materials can keep heat for a longer time than other materials, an indication of their higher thermal capacity.

1.1. Significance of inter-surfaces relationship in thermal remote sensing

Thermal remote sensing has experienced a significant development in recent years because it is economic and time-saving, and because of having many applications in various disciplines. Thermal remote sensing has application in water temperature mapping, land surface temperature mapping, air, water and land quality studies as well as in drought monitoring. Regarding an employment of the fast-growing field of thermal remote sensing, studies on a comparison of thermal and reflective data have been conducted. For an interpretation of thermal images, adequate information about the radiation from soil and from other surface features, temporal and spatial variations of these variables, as well as factors affecting kinetic temperature and thermal calculations of features are greatly needed. For an accurate and complete interpretation and for extraction of valuable needed information from thermal data, real world personal experience in accompany with theoretical knowledge is required.

Concerning the facilitation of remote sensing in the study of isolated regions, a study of Lut Desert using remote sensing has attracted many attentions. Due to the dangerous nature of direct involvement in studies of Lut Desert, several studies have used thermal data to measure surface temperature. Alavipanah et al. (2002) addressed the limitations of surface temperature mapping of Lut Desert using remotely sensed data. Komaki and Alavipanah (2005) used satellite data to study spectral separability of information classes in Lut Desert. Alavipanah et al (2005) studied diurnal behavior of land surface temperature using NOAA data in the region.

In the above-mentioned studies, a knowledge of such thermal characteristics as thermal conductivity, specific heat, thermal capacity, thermal diffusion, and thermal inertia are of importance in the study and interpretation of the temperature of features and of materials. Diurnal thermal variations of different features provide the interpreter with valuable information regarding type and condition of surfaces. The importance of these fluctuations is a provision of the ability to classify surface features using multitemporal thermal images based on their different thermal behavior which wasn't possible in case of similar behaviors. Fortunately, it happens only in two times of the day (sun rise and set) that some materials exhibit similar patterns and hence the images acquired are not usable in such studies. In other instances the type and characteristics of materials can be considered to be able to arrive at an accurate interpretation. The importance of daily thermal cycle was reported by Jensen using ATLAS airborne mission in a sandy bank of Mississippi. In this study which aimed at the separability of sand and gravel in thermal data, not distinguishable in air photos, ATLAS data with 2.5 m resolution (acquired at 5, and 10:30 AM (Ludz et al, 1999)) was used. A study of images (fig 1) shows that during daytime thermal image data of bands 10, 11 and 12, there is a significant difference observed between sand and gravel. The reason is the different thermal characteristics of these features which absorb different amounts of short-wave solar radiation and because of different warming levels emitting different amounts of long-wave thermal energy. This difference demonstrates itself as brighter tones of gravel as compared to sand in thermal infrared images (fig 1). During daytime water is cooler than the surroundings and is shown as darker tones. Vegetation cover near a river is cooler than the river itself and in the dawn time images it is expected to be warmer than the nearby regions while vegetation cover to be cooler than water. In these images also a significant difference is observable between sand and gravel surfaces although of less intensity than that during daytime (Jensen, 2000).

Several factors are effective in the selection of suitable time for acquisition of thermal image data. In other words, in the interpretation of thermal images periodical changes of temperature is useful. For an interpretation of thermal data a knowledge of faces and their composing materials as well as their alterations are needed. Such information can be the criterion for the selection of a proper thermal sensor system as well as for its interpretation. different overpass times of satellites and the resulting thermal variations should be considered in the interpretation of such data.

Soil with different minerals has different daytime surface temperatures and therefore exhibits itself as different tones (dark to bright). Regarding the time of image acquisition, the attained images would be different and their interpretation should be in connection with the overpass time of source satellite and of the thermal characteristics of the features. Therefore it is necessary for an image interpreter to have knowledge of the trend in surface temperature of different features in addition to knowledge of radiative temperature of features in different timeslots, and to use this knowledge for the selection of the type, time and for an interpretation of the selected images. Image acquisition of different sensor systems such as TM, ETM+, ASTER, MODIS and NOAA occurring in different times of the day, are important in the application of these images. Having a knowledge of diurnal cycle of surface temperature, the possibility of a prediction of the state of materials dependent upon the different hours of the day will be possible (Jensen, 2000). Due to the complexity of the materials forming different surfaces which influences their diurnal thermal behavior, the generalization of the results to other surfaces is not possible. For example thermal behavior of urban surfaces is different from that of the desert surfaces. Considering the above discussion the necessity of the study of thermal fluctuations of surface features in Lut Desert for the use of thermal images of these areas becomes obvious.

In this study, field observations of Lut Desert were analyzed. In the selection and application of thermal images and mission planning for airborne image acquisition, surface and near-surface temperature of selected features in Lut Desert were studied as regards the significance of diurnal changes of common features in Lut Desert. In this research it is tried to employ correlation coefficient as an index of separability of the studied features in a diurnal cycle as well as its implication in the acquisition interpretation and of thermal images. In the end the effective use of the results in the deployment of TIR data in connection with the separability of different features will be discussed.

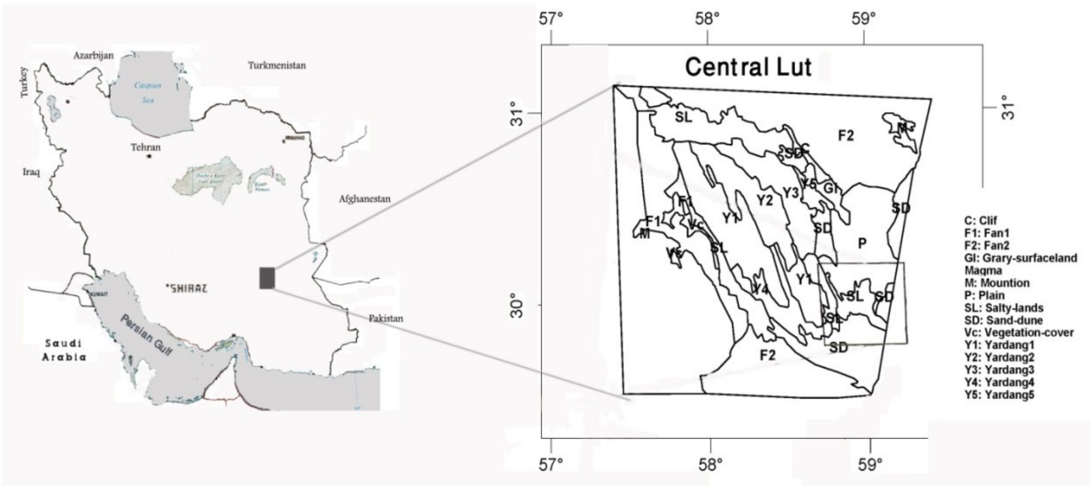

Fig. 1. The situation of the study area

2. Materials and Methods

2.1. The study area

Lut Desert SE, Iran, with an area of about 80000 km^2, is located between 28° 21′ & 32° 00′ N, and 55° 57′ & 57° 31′ E. In general, this region has been known to consist of three parts, namely northern, central and eastern Lut. Lut Desert, because of its geographic and climatic location on the arid belt of northern hemisphere, receives a great amount of solar radiation which together with a clear sky gives it hyper-arid climate conditions and makes it known to be the hottest region in the world by some researchers.

2.2. Data and Analysis

The methodology of this research consisted of 1) field observations 2) library studies 3) statistical analysis. In this study surface temperature of such features as marl, gray sand, bright sand, saline soil, 10 cm depth of soil (referred to as subsurface, hereafter) along with wet and dry temperatures in Lut Desert form September 4, 2001 to September 18, 2001 for a period 15 days and in 2 hour intervals (form 6 AM to 8 PM) were recorded in a controlled manner. The measurement of surface temperature of different features was carried out by experts in the Shahdad Weather Station using special thermometer for soil temperature, measurements. In addition library sources were employed to validate the obtained results. The analysis of the data was carried out through excel spreadsheet software. In order to examine the results of field observations the required graphs were produced. Correlation coefficients among different surface features were used to examine the inter-surface (between different surfaces) and hourly (temporal) relationships. The behavioral pattern of correlation coefficients of different features was examined from different viewpoints. The results were used to formulate the proper guideline in the use of thermal sensor data in the study of Lut Desert.

3. Results

According to the statistical analysis on the surface temperature data the following results were obtained. Investigating the recorded temperature in different diurnal cycles, Minimum SDs were found to be registered at 2 and 6 PM, with values of 0.06 and 0.13 respectively. Maximum SDs were registered at 8 AM and 8 PM with values of 0.25 and 0.24 respectively (table 1). In general, the frequency of minimum correlation coefficient SD among temperatures of features was observed at 8 AM and 4 PM, and the frequency of maximum SD at 10 AM and 2 PM (table 2).

Table 1. Average SD and variance of daily cycle of surface temperatures

Hours	6	8	10	12	14	16	18	20
SD	0.15	0.25	0.18	0.2	0.13	0.27	0.06	0.24
Variance	0.023	0.063	0.032	0.039	0.016	0.073	0.004	0.056

Table 2. 15 day average SD of temperatures of several features

Hours / Variables	6	8	10	12	14	16	18	20
Sand	2.34	1.69	1.88	2.65	2.91	2.29	2.87	2.4
Dark sand	1.8	1.7	3.1	2.2	2.8	2.1	2.3	2.1
Marl	2.3	1.48	2.41	2.05	2.61	1.47	2.35	2.22
Surface of salt	1.79	1.99	2.19	1.56	1.95	1.07	1.95	1.83
Dry air	2.77	2.27	2.59	2.51	2.36	2.13	2.46	2.87
10 cm depth	2.6	2.9	2.2	2.54	3.21	1.55	2.79	2.11
Wet air	1.6	1.58	2.29	1.67	1.85	2.15	1.74	1.22

Table 3. SD of different features temperatures in different hours of day in Lut Desert

Features	S-M	S-DS	DS-M	SS-S	SS-DS	SS-M	WT-S	WT-DS	WT-M	WT-SS	D10-S
SD	0.14	0.13	0.17	0.2	0.24	0.15	0.16	0.1	0.17	0.18	0.13
Features	D10-DS	D10-M	D10-SS	D10-WT	S-DT	DS-DT	M-DT	SS-DT	D10-DT	DT-WT	
SD	0.18	0.11	0.06	0.14	0.11	0.09	0.17	0.27	0.22	0.06	

With reference to the forthcoming graphs as well as table 3 minimum SD was observed between wet and dry temperatures as well as between subsurface and saline soil with a value of 0.06. Maximum SD was observed between temperatures of saline soil and dry air with a value of 0.27.

In the graph showing temporal pattern (Fig. *), 6 PM showed the lowest, while 4 AM and 8 PM the highest SDs. In this way, the least correlation coefficient (8 PM) was adjacent to the highest one (6 PM) which resulted in a sharp gradient. At 6 PM the correlation coefficient between temperature of sand-marl and sand-dark sand, subsurface-marl and subsurface-saline soil temperature reaches its highest value. In general, the correlation between wet and dry temperatures and other surfaces shows a reduced value in major hours of the day. The similarity of patterns 8(AM) to 4(PM) and 2(PM) to 6(PM) is clearer than that for the other hours. Diurnal patterns of correlation coefficient of temperature between all under-study surfaces were depicted in Fig. 2. This graph, due to its 15-day duration exhibits the variation of the correlation coefficients of different surfaces. Obviously, the existing correlation coefficient between soil-affected-soil and subsurface temperature show almost the highest value as compared to others during the day. Correlation coefficient between saline soil and dry temperature shows the highest variation, and at 8 PM it is insignificant with a value of -0.1.

Fig. 2 compares surfaces showing the highest correlation coefficients. Despite the high values of average correlation coefficient between sand-marl and sand-wet, they show the lowest value at 10 AM. In contrast, there is a significant relationship between sand-wet temperature records reaching its highest value at 12 AM. Also the relationship between their temperature trends is found to be weaker in the morning hours than in the afternoon. The graph illustrates the lowest significance at 10 AM and 8 PM while the highest at 4 and 6 PM between surfaces.

In Fig. 3 co-trend surfaces were extracted and hence surfaces with similar thermal characteristics shown. According to Fig. 3 the correlation coefficient of dry-soil, dry-subsurface temperature and the correlation value of subsurface temperature with wet, marl, dark sand and sand and also the correlation of dark sand temperature with saline soil and marl temperature show similar trends. Between these surface features the lowest significance level is observable at 4 PM and the highest one at 6 PM and later at 2 PM and 8 AM. Although there is a general similarity in the diurnal trend of correlation coefficient of these surfaces, a great disorder is exhibited between 10 and 12 AM.

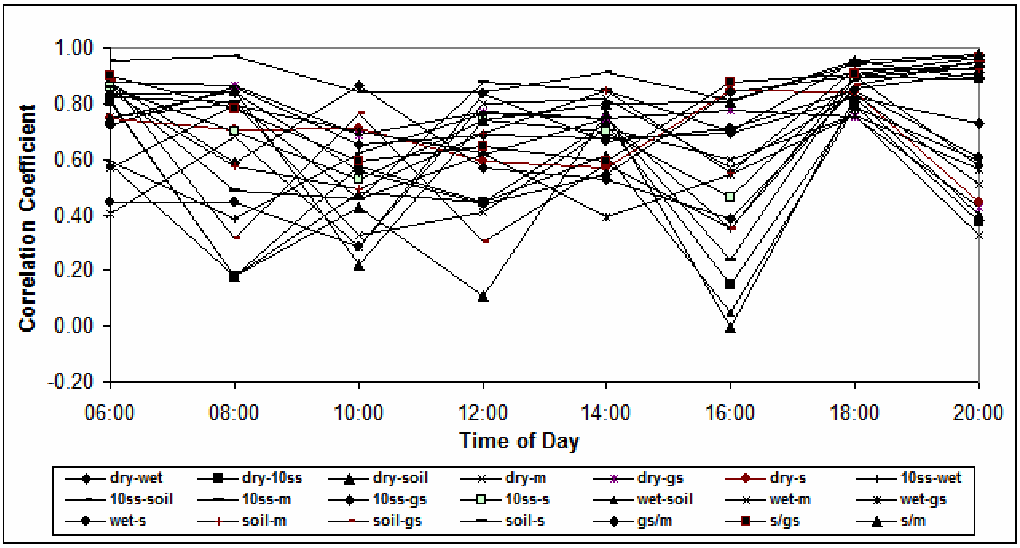

Fig. 2. Daily trend pattern of correlation coefficient of temperature between all under-study surfaces

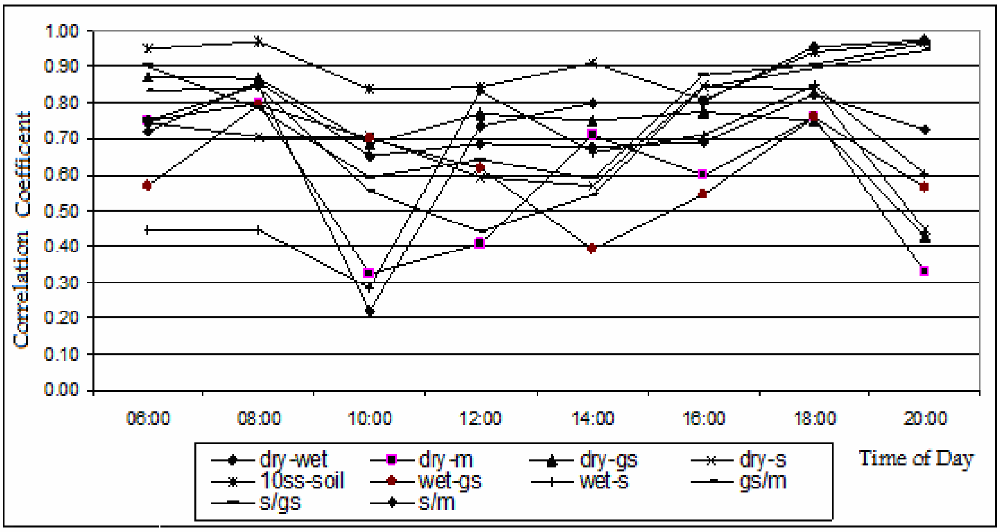

Fig.3. A comparison of correlation coefficient hourly trend pattern of temperature between surfaces with high average correlation during daytime

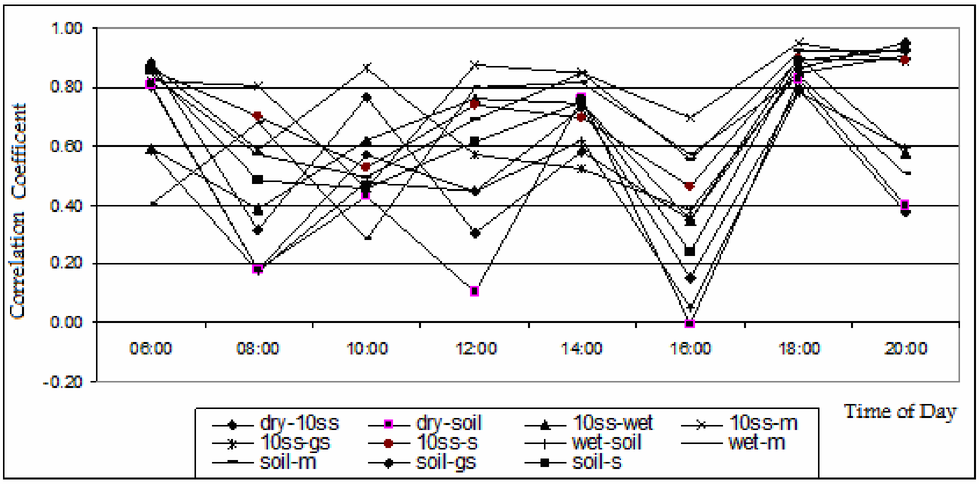

Fig. 4. A comparison of correlation coefficient hourly trend pattern of surfaces with similar trends

Figures 4 and 5 illustrate daily trends of correlation coefficient between soil, gray sand, marl and saline soil. There is a completely nonlinear trend observed in the morning hours. At 6 AM, 6 and 8 PM, in the absence of solar short wave radiation and decrease of albedo, the significance level of correlation coefficient among surfaces is high. Correlation coefficient of daily trend of temperature between sand-marl and saline soil-dark sand is completely different in the morning hours but in the afternoon the trend is linear (Fig. 5), while daily trend of correlation coefficient of saline soil-sand and sand-marl are in complete conformity (Fig6). This emphasizes inherent differences in thermal and physical characteristics of dark sand and other surface types.

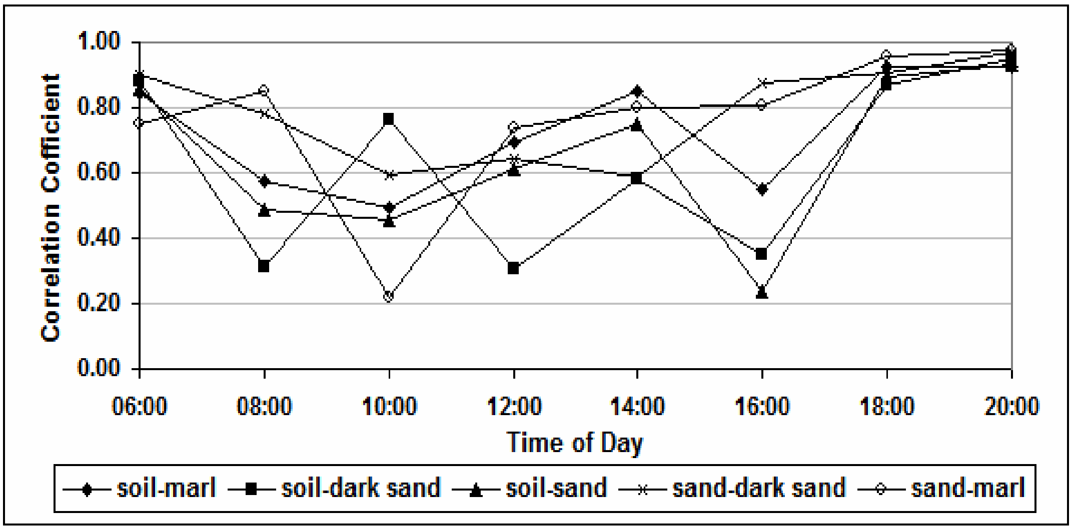

Fig. 5. A comparison of daily trend correlation coefficient of soil, sand, dark sand and marl

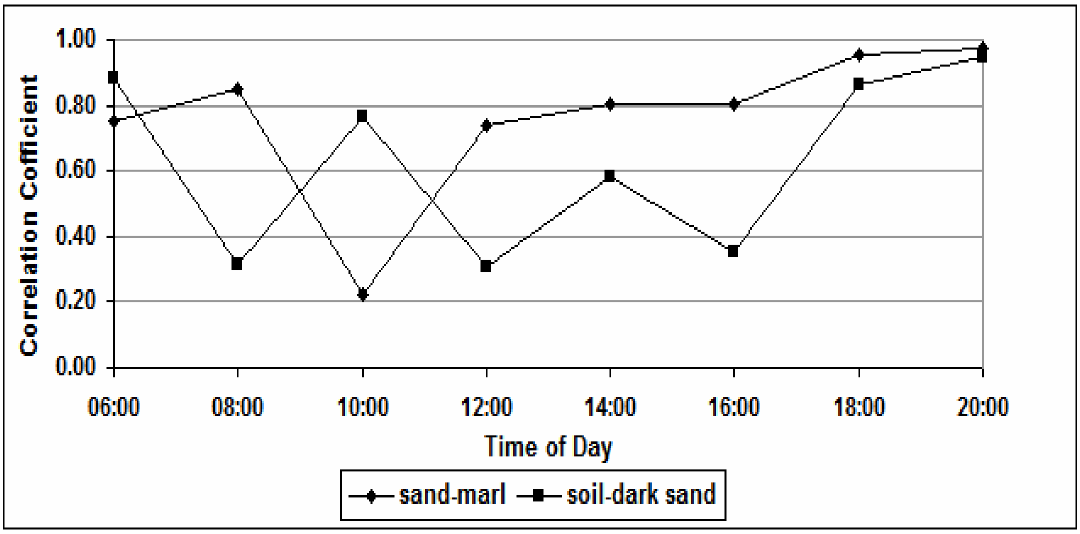

Fig. 6. A comparison of correlation coefficient of daily trend of sand, marl, soil, gray sand

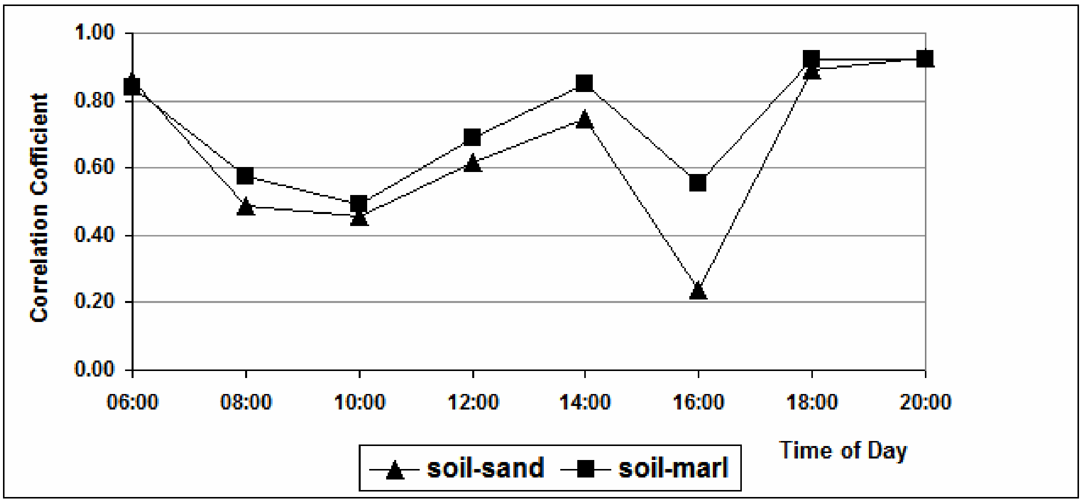

Fig. 7. A comparison of the average daily trend of correlation coefficient between soil, sand and soil, marl

The comparison of daily trend of correlation coefficient of saline soil and subsurface temperature with wet and dry temperature is important as regards the surface-atmosphere connection. Although the temperature records of saline soil and subsurface show significance, and there is a similar daily trend observed between dry-saline and wet-saline soil temperatures, but there isn’t any obvious pattern, exhibited.

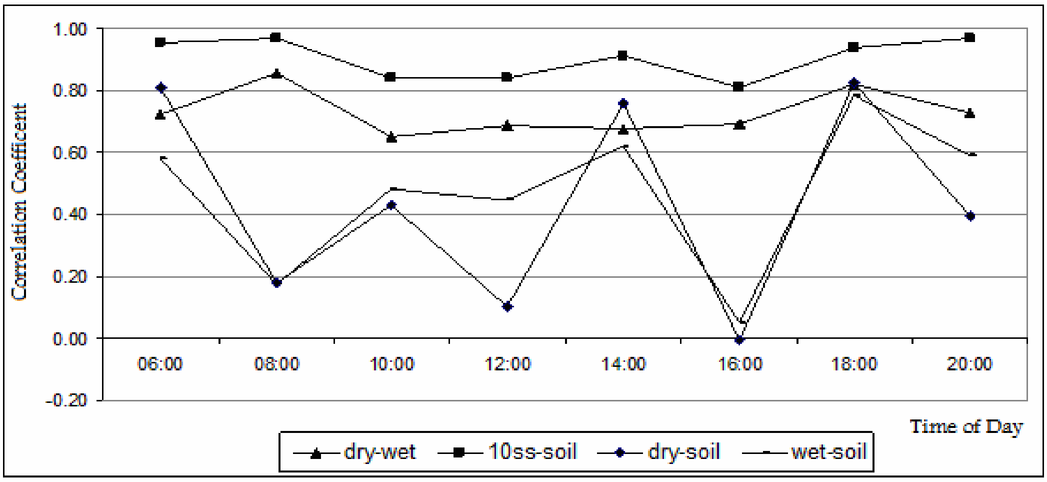

Fig. 8. A comparison of diurnal trend of correlation coefficient of soil and subsurface with wet and dry temperatures

The comparison of correlation coefficient pattern of surface features in midday hours (Fig. 8) doesn't reveal a similar trend and there are fluctuations observed especially at 8 PM which is a sign of variation in the significance level of correlation coefficient among surface features in midday hours. Between 10 and 14 AM there is an obvious difference evident in the significance level regarding surface types.

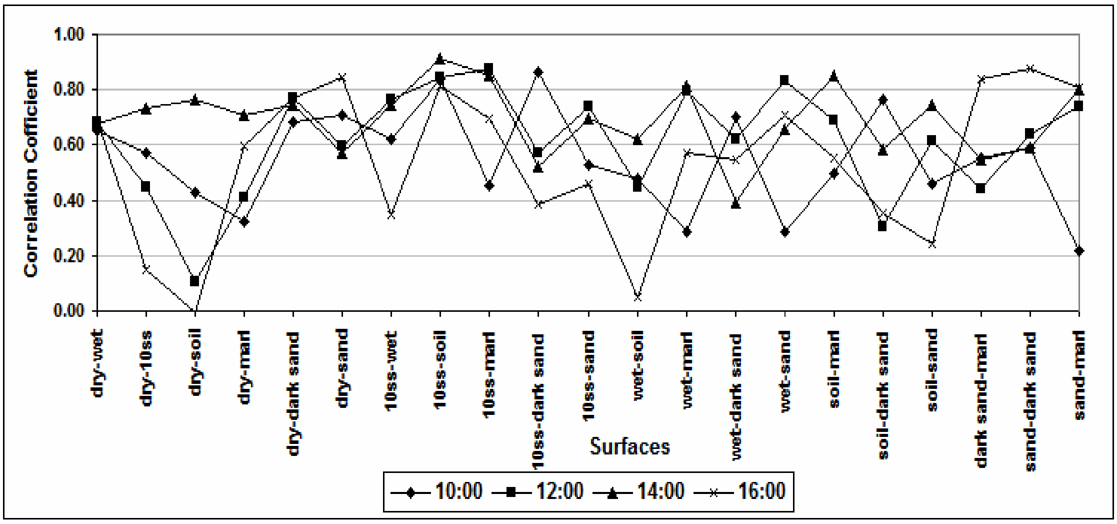

Fig. 9. A comparison of correlation coefficient pattern of different surfaces in midday hours

In a comparison between early and late hours of the day (Fig. 9) 8 AM shows the highest variation in correlation coefficient of surfaces among all time hours. At 8 AM the highest correlation coefficient is exhibited between soil and subsurface temperature and the lowest between soil-wet and soil-dry temperature. At 8 PM the lowest correlation coefficient is between day temperatures with other soil surfaces. At 6 AM correlation coefficient of wet temperature as compared to that of other surfaces is in its lowest state while other surfaces show high values for the correlation coefficient. The reason for such a low correlation coefficient between dry temperature and other surface features after sunset and its minimum value between wet temperature and other surfaces near sunrise hours is probably due to the higher relative humidity of surface features and hence with dry as well as due to the quick decrease in the temperature of different surfaces at night and an increase in relative humidity of air and surfaces specially saline and clay, soils.

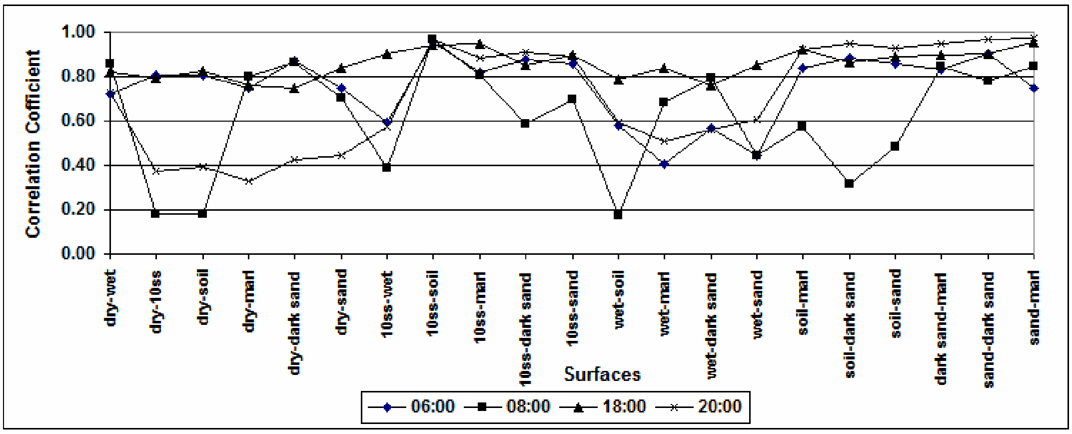

Fig. 10. A comparison of correlation coefficient pattern among surfaces in early and late hours of the day

The similarity of behavioral pattern between 8(AM)–4(PM) and 2–6(PM) is indicative of a clear dissimilarity when compared whit the other hours (fig.10). Diurnal trend of correlation coefficient of different surface features shows the best fit at 6 PM while the worst fit along with the lowest level of significance at 4 PM (fig. 11).

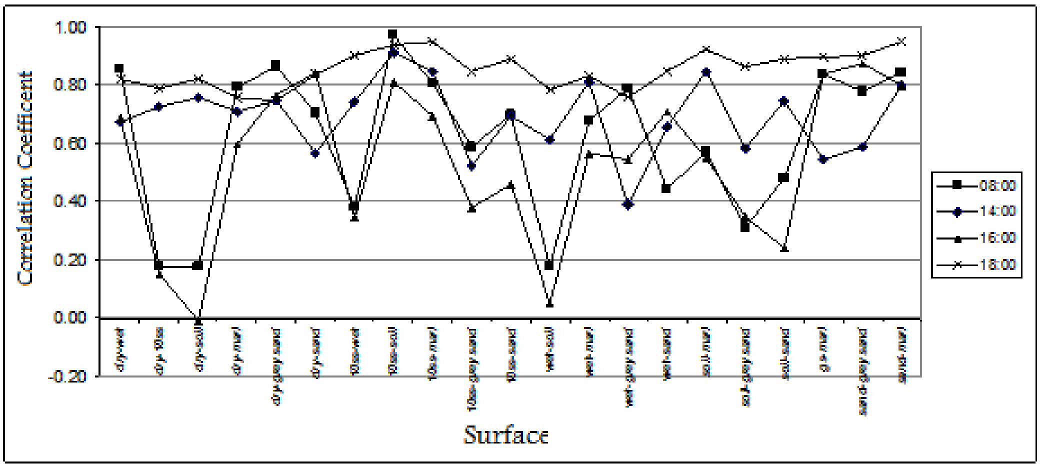

Fig. 11. A comparison of correlation coefficient trend of surfaces in co-trend hours of 8(AM) to 2(PM) and 4 to 6(PM)

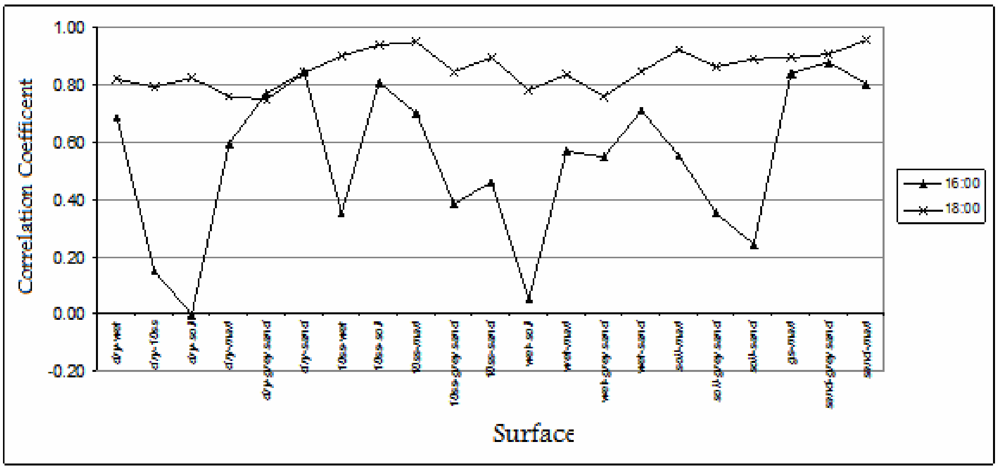

Fig.12. Correlation coefficient pattern of surface temperature of surfaces at 4 and 6 PM

Table 4 represents a summarization of the findings of this research. According to table 4, it is possible to select a proper image, taking into account the feature types that are of interest to the researchers. As observed, the occurrence time of highest correlation coefficient between two features and the occurrence time of two lowest consequent correlation coefficients are presented in the table. According to this table, the most suitable time for a distinction of two features in a thermal infrared image is around the time presented in the first (minimum) column of the table. The occurrence time of the highest correlation coefficient value is the least suitable time for image selection. It could be concluded from the table that with a specific image at hand it is not possible to separate all the features due to different occurrence times of maximum and minimum correlation coefficients. The second column for minimum correlation coefficient value is useable for an optimum state. In case the image acquired at first column is not accessible the second column is the next choice. Examining the table it becomes evident that 6 PM and 8 PM are the most frequent occurrence hours which show those images acquired at these hours are the least suitable images for the separation of the most under study features. This study is very important in design of image acquisition missions using aerial thermal sensors. Although the worst acquisition time is among the late hours of the day, namely crossover times, but in some cases this time coincides with morning hours or even midday. As observable from table 4 and 10 AM is the most frequent in the first and second minimum columns overlapping with overpass time of such thermal sensors as TM and ETM+ indicating that the designers of these sensors have taken this fact into account. Beyond 10 AM the most frequent time is 4 PM which is in overlap with local overpass time of NOAA. In case the image acquisition mission design for Lut Desert is intended, table 4 is a good guide for the researchers.

Table 4. The occurrence time for minimum and maximum correlation coefficient among different features

Feature	Min 1	Min 2	Max	Feature	Min 1	Min 2	Max	Feature	Min 1	Min 2	Max
wet-s	10	8	18	10ss-soil	16	10	8	dry-wet	10	12	8
soil-m	10	16	20	10ss-m	10	16	18	dry-10ss	16	8	14
soil-gs	12	8	20	10ss-gs	16	14	20	dry-soil	16	12	18
Soil-s	16	10	20	10ss-s	16	10	20	dry-m	10	20	18
gs-m	12	10	20	wet-soil	16	8	18	dry-gs	20	10	6
s-gs	10	14	20	wet-m	10	6	18	dry-s	20	14	16
s-m	10	12	20	wet-gs	14	6	8	10ss-wet	16	8	18

4. Discussion and Conclusion

The arid environment of desert, lacking the factors that can somehow control severe climatic conditions (humidity and vegetation cover) has caused different temperature patterns in different surface features in similar climatic conditions. This is in a way that different soil types and minerals show different reactions to solar radiation. With regard to the above discussion, the correlation between different surface features is relatively low, but more prominent in non-homogeneous features and in different time hours of the day, during which different patterns and surface thermal behaviors are observable. The following are results some of the obtained. The general trend pattern of correlation in different hours of the day shows a minimum at 4 PM, while a maximum at 6 PM. The correlation coefficient is relatively high at 6 AM and at 2 PM. There is nothing special about surface temperature at 8 AM while there is a clear distinction among temperatures of different surfaces. This behavioral disorder continues in midday hours (10AM to 2PM). High correspondence of correlation coefficient trend of surface temperature (saline and subsurface soil) during different hours of the day with other surface types shows their similar thermal characteristics. In the early and late hours of the day and in the absence of sunlight, different surfaces show similar physical and thermal characteristics of high correlation coefficients. Surfaces with low thermal conductivity and thermal capacity start giving out long wave radiation as the sun gradually stops radiating. They quickly become cool due to their low penetration rate of heat energy. In contrast, other surfaces with high thermal capacity and conductivity due to their higher thermal stability, would have similar temperature, during the early hours of the night. In midday hours which are the hour of highest sun radiation, surface features show different reactions based on their thermal and physical characteristics. Therefore during these hours of the day any clear and significance relationship among correlation coefficient patterns is not observable.

The study of correlation coefficient of different surface types during the day reveals a disorder in midday hours which is related to EMR and to physical, chemical, and thermal characteristics of different surface types in interaction with short-wave solar radiations. On the whole, significance level during morning hours is indicative of low thermal conductivity and capacity as well as their different reactions (by the start of sun radiation). Dry air temperature has the least correlation coefficient with other surfaces during the daily hours. Subsurface records with an SD of 0.138 have the highest correlation coefficient with other surfaces. A temperature of 5.8 °C shows the least daily variation range. Also the correlation coefficient between dark sand and wet temperature with an SD of 0.09 shows a good agreement. Distinction in correlation coefficient value in such early hours as 4 PM and 6 PM as well as the difference in behavioral pattern of correlation coefficients during midday hours shows that different surfaces and minerals exhibit different reactions when exposed to short wave solar radiations. In midday hours due to different albedos between soil surfaces, the thermal difference increase while during the early and late hours of the day due to reduction in solar radiations, thermal differences reduce. In a way, higher variation range of temperature apart from saline soil, is observable between 10 AM and 12 AM with a value of 8 °C. In saline soils regarding the thermal characteristics and the albedo of salt crust it occurs between 8 AM to 10 AM with a value of 8 °C. It should be noticed that thermal and microclimatic conditions of different surfaces are functions of environmental microclimatic conditions and the change in climatic conditions is effective in thermal behavior pattern of surface temperatures.

The results summarized in table 4 indicate that TIR data acquired in morning hours and the midday images are the best options for separation of different feature and types of soil, based on thermal differences. In contrast it is concluded that other images including early and late as well as night images are not suitable for such a practice. Regarding the above-mentioned results it could be concluded that thermal data acquired through ETM+ due to its relative advantages such as higher spatial resolution, and in the non accessibility of TM, is the best choice because it offers the possibility to map most of the surface features studied here and hence is recommended in the future studies of Lut Desert.

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