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Cover

Thermal variation in the Israel-Sinai (Egypt) peninsula region

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Surrounded by Mediterranean Sea in the north-west and Gulfs of Suez and Aqaba of Red Sea in south, the Israel-Sinai (Egypt) peninsula is a unique and special region in the world. Historically, this region was the origination centre of the world's three main religions: Judaism, Islamism and Christianity and consequently it was appraised as the Holy Land. Contemporarily, the political and ideological conflicts between Jewish and Arab branded it as one of the hottest places in the world. Standing geographically at the crossroads of Europe, Asia and Africa as well as locating geologically at the junction of African continent and Middle East plate, the region is not only interpreted as of geopolitical importance in global strategies but it is also characterized with obvious landscape and climate differences. Rich rainfall in the Mediterranean coastal region and northern Israel produces its unique climate pattern and dense vegetation cover features. In contrast, bare rocky mounts and valleys with extremely drought desert environmental ecosystem are the prevalent landscape in the central and southern Sinai. Three natural zones can be distinguished in the region: Mediterranean climate area, savannah, and desert. These unique features have attracted many scientific studies oriented to the region (Ritter 1968, Ostendorff *et al.* 1976, Danin 1983, Neev *et al.* 1987, Karnieli and Tsoar 1995; Yair *et al.* 1997). The estimation of land surface temperature (LST) for assessment of its spatial variation in the region, however, still remains as an untouched topic due to many difficulties. The availability of remote sensing data, especially NOAA-AVHRR covering the whole scene of the region, provides a possibility for the assessment of LST variation in such a vast region.

The retrieval of LST from NOAA-AVHRR data with two thermal channels (4 and 5) separately operating in 10.5–11.3 μm and 11.5–12.5 μm is mainly through the application of so-called split window algorithm technique. Several kinds of split window algorithms have been developed and proposed in the last twenty years on

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the basis of various considerations on the atmosphere and the emitting surface (Vogt 1996, Cracknell 1997, Qin and Karnieli 1999). The existing algorithms such as Sobrino *et al.* (1991), Prata (1993) and França and Cracknell (1994) usually involve not only the essential parameters of atmospheric transmittance and ground emissivity but also other atmospheric parameters that are generally difficult to estimate due to the lack of *in situ* atmospheric profile data. In order to assess the spatial distribution of LST in the Israel-Sinai (Egypt) peninsula region, a better split window algorithm only requiring the two necessary parameters (emissivity and transmittance) has been derived on the basis of thermal radiance transfer equation (Qin *et al.* 1999). This algorithm and the methodology for determining its coefficients have been used to retrieve the LST distribution of the peninsula region from NOAA-AVHRR data. Figure 1, also on the cover, shows the result of this retrieval effort, i.e. the spatial variation of land surface temperature of the region. The original image used to produce the thermal image in figure 1 was acquired by NOAA-AVHRR 14 on

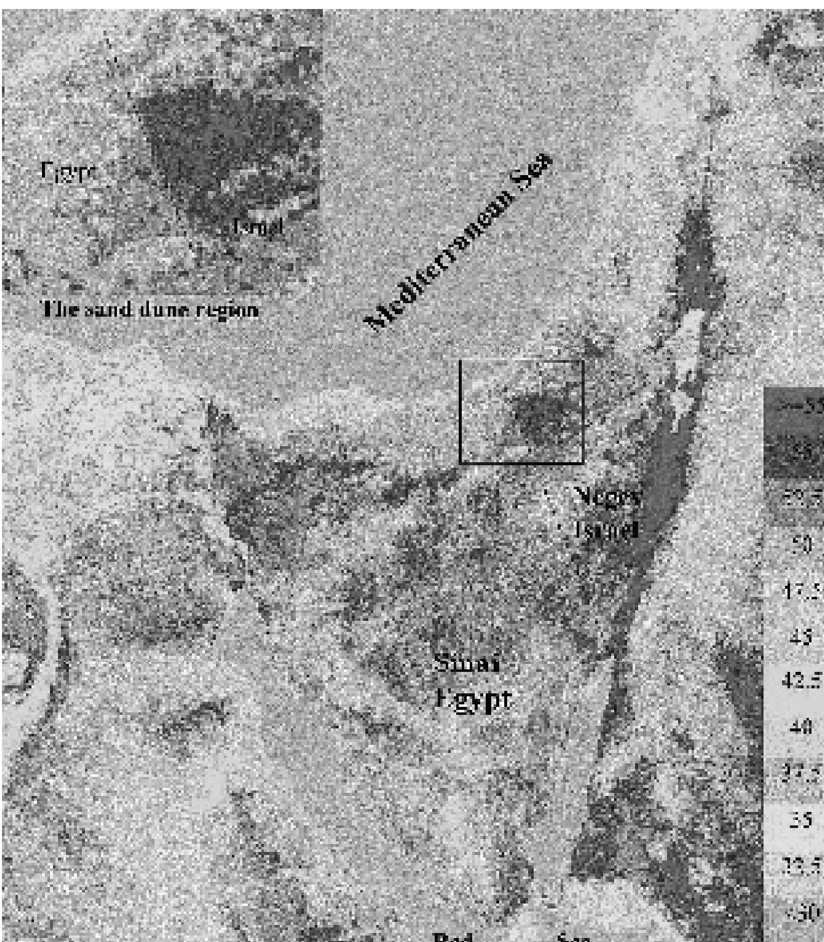

Figure 1. The thermal image of the Israel-Sinai (Egypt) peninsula region, showing the spatial variation of LST distribution in the region. A sharp contrast of LST change can be clearly seen on both sides of the Israel-Egypt border in the sand dune region.

18 July, 1998 at about 12:08 GMT or 3:08 p.m. local time with a zenith viewing angle of 83.7° and contains five channels. Figure 2 is composed of channels 1, 2 and 4 of the original image as RGB, showing the landscape of the peninsula region. A sharp contrast of spectral reflectance can be clearly seen on both sides of the Israel-Egypt border. This contrast was interpreted as the direct result of different vegetation cover and biogenic crust percentage on both sides (Karnieli and Tsoar 1995). The dark tone in the south of the peninsula and the coast of Aqaba Gulf is mainly due to the dark metamorphic and basaltic rocks in these mountainous areas.

The climate of the region can be generally divided into two patterns. Wet and cool winter season ranges from November to April of the following year. The rest from May to October is characterized as the dry and hot period. July when the original image was acquired is a very dry and very hot month of the year in the region. As shown from figure 1, three spatial patterns of LST distribution can be clearly identified. Extremely high LST mainly concentrates in the central Sinai and southern Jordan River valley and the western Saudi Arabic sandy desert beside Red

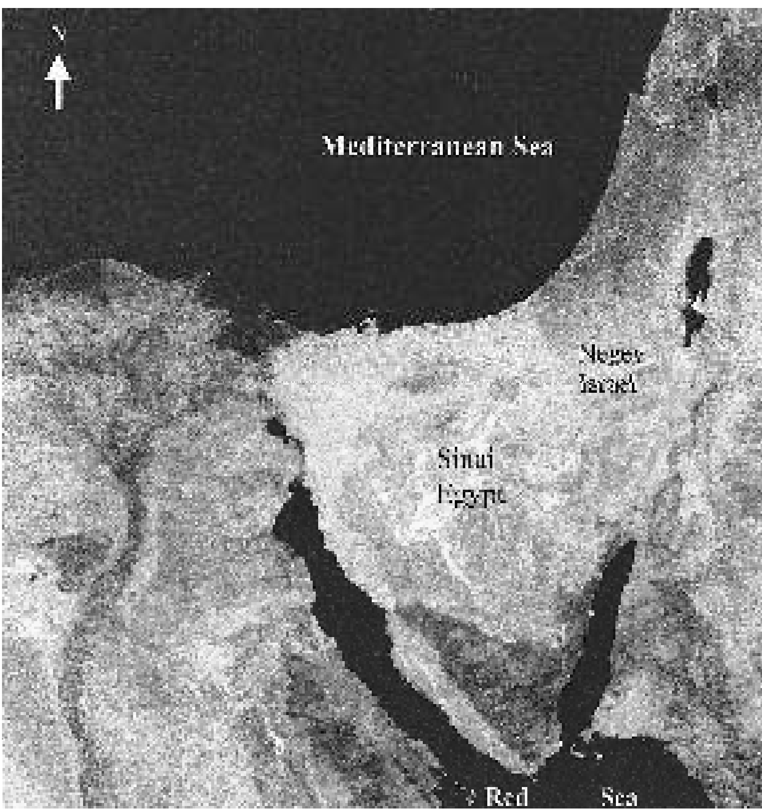

Figure 2. The pseudo colour image of the Israel-Sinai (Egypt) peninsula region, composed of NOAA-AVHRR-14 channel 1, 2 and 4 as RGB. This image was acquired on 18 July, 1998 at about 12:08 GMT or 3:08 pm local time with a zenith viewing angle of 83.7°. A sharp contrast of spectral reflectance can be clearly seen on both sides of the Israel-Egypt border. This contrast was interpreted as the direct result of different vegetation cover and biogenic crust percentage on both sides. The dark tone in the south of the peninsula and the coast of Aqaba Gulf is mainly due to the dark metamorphic and basaltic rocks in these mountainous areas.

Sea. LST in these areas can be found to reach high up to 52–55°C. In northern Israel coastal area, the Nile delta and Nile river plain, the LST is much lower (<45°C). This is quite reasonable because these areas have much more vegetation cover and/or soil water content. Agricultural activities of the region are mainly concentrated in these areas. Between these two extreme patterns is the one seen in most areas of the region, especially in the Egyptian side of the sand dune region, the eastern Egypt desert and the western Jordan. LST of these areas ranges from 45°C to 50°C, which is the typical land surface temperature range of the arid region in the hot summer season. There are some spots with low LST (<45°C) scattering in the south of the peninsula and the east of Red Sea to Jordan River valley. This is mainly attributed to the high altitude of the mountain area, where the famous Jabal Katrina peak has an altitude of 2637 m.

One interesting LST phenomenon of this thermal variation image is in the sand dune region across Israel-Egypt border (the insert in figure 1), where we can see an obvious contrast of LST on both sides of the border. Due to different land use and natural conservation policies, the Israeli side has more vegetation (desert shrubs) cover than the Egyptian side where bare sand dunes are prevalent (Otterman *et al.* 1975, Karnieli and Tsoar 1995, Pinker and Karnieli 1995, Karnieli and Sarafis 1996, Tsoar and Karnieli 1996, Karnieli 1997). However, the LST on the Israeli side is higher than on the Egyptian side. In regular conditions, one might think that since the Israeli side has more higher plants that contribute to regional evapotranspiration, it should be cooler than the Egyptian side. Such phenomenon has been observed across the border between USA and Mexico (Balling 1989). Two reasons can be used to provide an explanation to the reverse thermal variation in our region: (1) The sand dunes on the Israeli side are almost covered by soil biogenic crust, with 1–5mm thickness and low albedo hence dark tone in the visible-band images, which absorbs more incident radiation and emits stronger thermal radiance than the bare sand on the Egyptian side; (2) Although more higher vegetation on the Israeli side, but these desert plants due to their scarcity and dormancy in the dry and hot summer almost contribute nothing to the regional evapotranspiration that cools down the surface. Detailed examination of the phenomenon has been addressed in Qin (1999).

Precise LST estimation in such a vast region with above 800 km × 800 km usually requires the known atmospheric profile data of several locations *in situ* satellite pass. However, such data is not available for our estimation. The atmospheric transmittance used by the algorithm to retrieve LST of the image is based on the measurements of sunphotometer CIMEL located at Sede Boker in central Israeli desert. In addition to aerosol optical thickness, the instrument also measures water vapour content in atmospheric profile with an accuracy of about $0.2\,g\,cm^{-2}$. According to our sensitivity analysis of the algorithm, the maximal LST estimation error caused by the possible measurement error would be about 0.28°C on average (Qin *et al.* 1999). The atmospheric profile in the arid region is relative identical in terms of water vapour content. Under this assumption, the measurement of atmospheric water vapour content at Sede Boker can be extended to represent the general case of central Sinai desert. The possible LST estimation error due to transmittance error is expected to be at the acceptable level of about 0.5–0.7°C for most places of the region. The estimation of ground emissivity for LST retrieval is very complicated and we use a range of 0.95–0.97 for the LST retrieval. Assuming a potential error of 0.01 in our estimation, the possible LST error is expected to be within 0.71°C for most areas of the region. Therefore, considering the combination effect of possible transmittance and emissivity errors, the probable LST error is estimated to be within $\pm 1.5°$C (Qin *et al.* 1999). This accuracy of LST estimation is generally acceptable for assessing the spatial variation of thermal distribution in such a vast region.

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