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Determination of land surface temperature using precipitable water based Split-Window and Artificial Neural Network in Turkey

B. Yiğit Yıldız [a,*], Mehmet Şahin [b,1], Ozan Şenkal [c,2], Vedat Peştimalci [d,3], Kadir Tepecik [e,4]

[a] Karaisalı Vocational School, Çukurova University, 01770 Karaisalı, Adana, Turkey
[b] Department of Electrical and Electronic Engineering, Siirt University, 56100 Siirt, Turkey
[c] Department of Computer Education and Instructional Technology, 01330 Saricam, Adana, Turkey
[d] Physics Department, Çukurova University, 01330 Saricam, Adana, Turkey
[e] Turkish Republic State Meteorological Service, 01120 Yüregir, Adana, Turkey

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Abstract

Land surface temperature (LST) calculation utilizing satellite thermal images is very difficult due to the great temporal variance of atmospheric water vapor in the atmosphere which strongly affects the thermal radiance incoming to satellite sensors. In this study, Split-Window (SW) and Radial Basis Function (RBF) methods were utilized for prediction of LST using precipitable water for Turkey. Coll 94 Split-Window algorithm was modified using regional precipitable water values estimated from upper-air Radiosond observations for the years 1990–2007 and Local Split-Window (LSW) algorithms were generated for the study area. Using local algorithms and Advanced Very High Resolution Radiometer (AVHRR) data, monthly mean daily sum LST values were calculated. In RBF method latitude, longitude, altitude, surface emissivity, sun shine duration and precipitable water values were used as input variables of the structure. Correlation coefficients between estimated and measured LST values were obtained as 99.23% (for RBF) and 94.48% (for LSW) at 00:00 UTC and 92.77% (for RBF) and 89.98% (for LSW) at 12:00 UTC. These meaningful statistical results suggest that RBF and LSW methods could be used for LST calculation.

Keywords: Thermal satellite data; LST; PW; ANN; Split-Window

1. Introduction

A grooving amount of remote sensing studies have showed that products of satellite images could be very useful for researcher in different research areas. An important physical variable, LST could be calculated successfully enough as a product of meteorological satellite images because satellites have the ability of observing the Earth's surface periodically with various sensors at different wavelengths within a long period of time and with suitable pixel resolution. These advantages enable researchers to use the satellite data to estimate the LST required for a wide variety of scientific studies such as energy budget models, evapotranspiration models estimating soil moisture, forest fire detecting, monitoring and forecasting of weather, climate change, studying land and sea breezes. The overall results of some remote sensing studies demonstrated that the AVHRR derived surface temperature has great usages

* Corresponding author. Tel.: +90 322 551 2057; fax: +90 322 551 2255.
E-mail addresses: yildizy@cu.edu.tr (B.Y. Yıldız), sahanmehmet2000@yahoo.com (M. Şahin), osenkal@cu.edu.tr (O. Şenkal), vedatp@cu.edu.tr (V. Peştimalci), kadirtepecik@gmail.com (K. Tepecik).
[1] Tel.: +90 484 2231224; fax: +90 484 2236631.
[2] Tel.: +90 322 3386355; fax: +90 322 3386440.
[3] Tel.: +90 322 3386425; fax: +90 322 3386070.
[4] Tel.: +90 322 3211398; fax: +90 322 3211605.

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in regional agricultural meteorology studies (De Wit et al., 2004). In order for the retrieval of LST over land surfaces from satellite data, various researchers have performed a formulation which uses the thermal channel4 and channel5 of NOAA–AVHRR and called as Split-Window method. These techniques based basically on AVHRR adjacent thermal channels which are affected distinctly from water vapor. The absorption by the water vapor continuum in channel4 (Ch4) is higher in than in channel5 (Ch5) (Quaidrari et al., 2002). Various SW algorithms have been generated for LST calculation by simulating the radiative response of the atmosphere at AVHRR thermal channel's regions for different atmospheric situations (Price, 1984; Becker and Li, 1990; Sobrino et al., 1991; Coll and Caselles, 1997; Kant and Badarinath, 2000).

Most of these SW algorithms have empirical coefficients and because of that they are confined for specific studies or study areas (Zoung et al., 2010). A great part of these Split-Window algorithms depending on emissivity values of land surfaces where affects of atmospheric water vapor on satellite data absolutely ignored or used as a constant value. Although in such Split-Window algorithms emissivity of land surface is primary important factor (Becker and Li, 1990; Vidal, 1991; Sobrino et al., 1991; Prata and Platt, 1991; Ulivieri et al., 1996) water vapor amount in the atmosphere is an another important parameter like emissivity which can change the outgoing radiation from the Earth's surface to satellites. The water vapor distribution in a vertical column has great importance for the quantitative description of infrared radiation, emitted by the atmosphere. It has great influence on the appraisal of precipitable water seasonal variations Kiehl and Briegleb (1992).

Precipitable Water (PW) is a meteorological parameter, which is described as total atmospheric water vapor amount in a vertical column between the surface of Earth and upper levels of atmosphere. It has been proved that PW in atmosphere has great impact by the correction of thermal satellite data for LST calculation (Barton, 1991; Becker and Li, 1990; Caselles et al., 1997; Sobrino et al., 1991). Thermal satellite data for LST calculation needs some major corrections for estimating valuable results; one is the atmospheric correction of the atmospheric water vapor and the other is surface emissivity of the study area. Because of these reasons, we decided on Coll et al. (1994) algorithm, which can be modified local PW and emissivity values.

In some previous studies, specific Artificial Neural Network (ANN) structures have been improved and used successfully in atmospheric science, climate change and LST studies (Pasini and Ameli, 2003; Antenello et al., 2006; Şahin, 2012; Şahin et al., 2012).

RBF method, an important ANN structure, was used in this study for predicting LST values. The input parameters used in RBF function are latitude, longitude, altitude which are geographic parameters, atmospheric water vapor amount, sun shine duration and surface emissivity.

The aims of this research was by utilizing the RBF and SW methods in LST calculation and validate the results with meteorology station values to suggest a suitable and useful LST calculation method for the locations where input parameters of models are available. Although there are some articles in the literature calculating LST using RBF method, we used PW and sun shine duration, not used before in such studies, as input parameter of RBF method. The other goal of the study is to generate Local Split-Window (LSW) algorithms for Turkey using Radiosond PW data and checking the validity of algorithms by calculating LST values.

2. Study area

The research area, Turkey is surrounded by the Aegean Sea, Black Sea and the Mediterranean Sea with geographic coordinate's 26°E–45°E and 36°N–42°N where the continents Europe and Asia intercepts. The LST calculation in the study was performed by using Radiosond data, satellite data and geographical data. There are five Radiosond stations (Adana, Ankara, İstanbul, Samsun and İzmir) in Turkey. These Radiosond stations are located by TMS at several cities of Turkey so that they have different climate conditions and have the ability to form a general overview of the meteorological parameters of Turkey. The geographic coordinates and altitudes of Radiosond stations are seen in Table 1.

The meteorological parameter (PW) used in this study were regularly measured by Radiosond observations from 1990 to 2007 twice a day (at 00:00 and 12:00) on the study area in Turkey (26–45°E and 36–42°N).

3. Data and methodology

3.1. Data and calibration

The SW method has been utilized to calculate the monthly LST values from AVHRR data with a pixel resolution of 1.1 km. The AVHRR sensor onboard of NOAA series satellite has five spectral bands in the visible, near-infrared and three in the thermal infrared region in Sun-synchronous orbits. The two of them (Ch4–Ch5) are sensing the land surface at 10.3–11.3 and 11.5–12.5 μm wavelengths and were designed for several thermal studies but widely used in LST calculations. A major advantage of NOAA satellites is, they are scanning the same area two times in a day with a nadir view of ±55.4° (Jang et al., 2004).

Table 1
The geographic coordinates and altitudes of Radiosond stations.

Stations	Latitude (°)	Longitude (°)	Altitude (m)
Adana	36.59	35.21	27
Ankara	39.57	32.53	891
İstanbul	41.01	28.59	0
İzmir	38.26	27.10	29
Samsun	41.17	36.18	4