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Prediction of high spatio-temporal resolution land surface temperature under cloudy conditions using microwave vegetation index and ANN

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Land Surface Temperature (LST) with high spatio-temporal resolution is in demand for hydrology, climate change, ecology, urban climate and environmental studies, etc. Moderate Resolution Imaging Spectroradiometer (MODIS) is one of the most commonly used sensors owing to its high spatial and temporal availability over the globe, but is incapable of providing LST data under cloudy conditions, resulting in gaps in the data. In contrast, microwave measurements have a capability to penetrate under clouds. The current study proposes a methodology by exploring this property to predict high spatio-temporal resolution LST under cloudy conditions during daytime and nighttime without employing in-situ LST measurements. To achieve this, Artificial Neural Networks (ANNs) based models are employed for different land cover classes, utilizing Microwave Polarization Difference Index (MPDI) at finer resolution with ancillary data. MPDI was derived using resampled (from 0.25° to 1 km) brightness temperatures (T_b) at 36.5 GHz channel of dual polarization from Advance Microwave Scanning Radiometer (AMSR)-Earth Observing System and AMSR2 sensors. The proposed methodology is tested over Cauvery basin in India and the performance of the model is quantitatively evaluated through performance measures such as correlation coefficient (r), Nash Sutcliffe Efficiency (NSE) and Root Mean Square Error (RMSE). Results revealed that during daytime, AMSR-E(AMSR2) derived LST under clear sky conditions corresponds well with MODIS LST resulting in values of r ranging from 0.76(0.78) to 0.90(0.96), RMSE from 1.76(1.86) K to 4.34(4.00) K and NSE from 0.58(0.61) to 0.81(0.90) for different land cover classes. During nighttime, r values ranged from 0.76(0.56) to 0.87(0.90), RMSE from 1.71(1.70) K to 2.43(2.12) K and NSE from 0.43 (0.28) to 0.80(0.81) for different land cover classes. RMSE values found between predicted LST and MODIS LST during daytime under clear sky conditions were within acceptable limits. Under cloudy conditions, results of microwave derived LST were evaluated with air temperature (T_a) and indicate that the approach performed well with RMSE values lesser than the results obtained under clear sky conditions for land cover classes for both day and nighttimes.

1. Introduction

Land Surface Temperature (LST) is the radiative skin temperature of the uppermost part of the earth's surface. It is a primary element in the fields of climate change, hydrology, energy balance models, vegetation monitoring urban climate and environmental studies because it represents integrated features of land atmosphere physical and dynamic processes (Choi et al., 2009; Jin, 2000; Wang and Dickinson, 2012; Li et al., 2013). Due to its rapid variations in both temporal and spatial scales, ground based observations of LST over large areas have become inept. With an advancement of remote sensing techniques, LST observations from the satellite data have emerged as the only viable way to provide data of high spatial and temporal resolutions over the entire globe. Mostly LST measurements are retrieved from the thermal infrared bands of sensors such as Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Very High Resolution Radiometer (AVHRR), Enhanced Thematic Mapper plus (ETM+) etc. In the past few decades, researchers have developed generalized split window algorithm, day and night algorithm or three channel LST algorithms to estimate LST (Li et al., 2013; Pandya et al., 2014). However, these sensors are strongly influenced by cloud, atmospheric water content and aerosols and hence fail to provide data under these scenarios.

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This results in paucity of LST data for many applications. Usually, 50% of the earth surface is covered by clouds at any time which significantly modifies the surface energy budget (Jin, 2000; Kustas and Norman, 1996). Normally, LST forms an integral part in the methods to estimate sensible, latent heat fluxes and soil moisture; hence it is essential to estimate LST even under overcast conditions. Researchers have attempted to derive high spatio-temporal resolution of LST under cloudy conditions using infrared sensors. Jin and Dickinson (2000) proposed the methodology to estimate LST under cloudy pixels using neighboring clear pixels with the surface energy balance equation based physical algorithm. This approach may not work in the case of difficulty in finding any neighbor clear pixel spatially and temporally. Lu et al. (2011) developed a methodology to retrieve LST under clouds from Meteosat Second Generation/Scanning-Enhanced Visible and Infrared Imager (MSG/SEVIRI) using temporal neighboring-pixel approach. This approach can be applicable only to daytime measurements. Hengl et al. (2012) predicted spatio-temporal daily temperatures using MODIS LST images

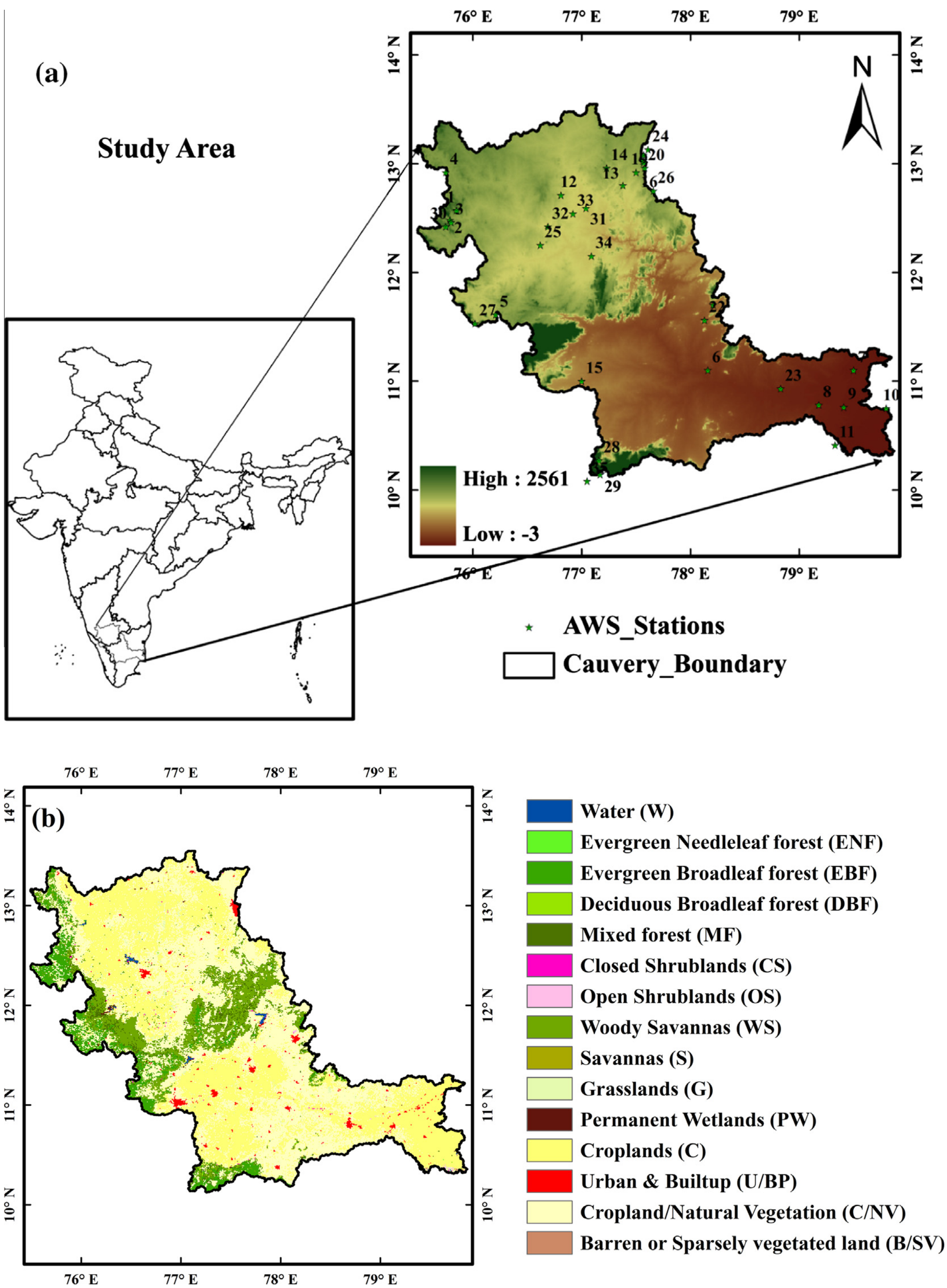

Fig. 1. (a) Location of the study area along with elevation changes. Automatic weather stations and its land cover types indicated by numbers (Station ID 1–3 belong to EBF, station ID 4–5 belong to WS, station ID 6–14 belong to C, station ID 15–18 belong to U & BP and station ID 19–35 belong to C & NV land cover classes) and (b) land cover classes in the study area.