ESTIMATION OF DAILY EVAPOTRANSPIRATION BASED ON MULTI-SATELLITE DATA OVER EAST ASIA

Soo-Jae Park[1], Youngmi Kim[1], Mi-Lim Ou[1], Young-Hwa Kim[1] and Kyung-Soo Han[2]

[1] Korea Meteorological Administration/National Institute of Meteorological Research, 61, 16-gil Yeouidaebang-ro, Dongjak-Gu, Seoul, Republic of Korea
[2]Department of Spatial Information Engineering, Pukyoung National University, Daeyeon Campus 45, Yongso-ro, Nam-Gu, Busan, Republic of Korea

ABSTRACT

The National Institute of Meteorological Research at the Korea Meteorological Administration (KMA/NIMR) has developed an algorithm of NIMR daily actual evapotranspiation (AET) estimation with multi-satellite data such as the Communication, Ocean and Meteorological Satellite (COMS) level 2 product (land surface temperature, insolation, Infrared channel data) and the SPOT/VGT product over the East Asia region (20°~50°N, 100°~145°E). The estimated evapotranspiration (ET) based on surface energy balance is 1 km spatial resolution on a daily basis. To determine the sensible heat fluxes, the match-up database (MDB) is constructed using satellite and ground-based measurement data over East Asia. The main characteristic of this algorithm is that it produces spatially distributed actual evapotranspiration data on a regional scale considering spatio-temporal varying surface roughness length of vegetation and land cover type. The NIMR ET shows regional and seasonal variability and its magnitude is 0 to 8 mm/day. To evaluate the NIMR AET, we compared it with the flux-tower observation data from the Korean Peninsula and with MODIS ET data gathered over East Asia. The NIMR AET data is good reflection of the regional environment of East Asia

INTRODUCTION

Evapotranspiration is an important component of the terrestrial hydrological cycle and energy budget between the land surface and the atmosphere on a regional to global scale in the climate system. The evapotranspiration study utilizes such input parameters as climate model, soil moisture and change in surface energy balance. Evapotranspiration is observed using a lysimeter, an evaporation fan and flux-tower measurements on the ground. However, this method at a point scale needs too many meteorological stations. The spatially distributed evapotranspiration at regional scales is obtained using remote sensing techniques. The satellite-based method has a wide spatial and a various temporal resolution. For this study, the KMA/NIMR developed the evapotranspiration retrieval algorithm based on multi-satellite (COMS, SPOT/VGT) data and the algorithm is evaluated.

EVAPOTRANSPIRATION ALGRORITHM

The KMA/NIMR used the so-called simplified method for determining the accumulated daily actual evapotranspiration first proposed by Jackson et al (1977). Latent heat fluxes (LE, $W{\cdot}m^2$), evapotranspiration, were calculated as the residual in the surface energy balance, namely LE = Rn-G-H. LE is the latent heat flux density, a function of the evapotranspiration rate, E ($kg{\cdot}s^{-1}{\cdot}m^{-2}$) and heat of vaporization, L ($J{\cdot}kg^{-1}$). Rn ($W{\cdot}m^2$) is the net radiation flux, H is the sensible heat flux density ($W{\cdot}m^2$) and G is the soil heat flux density ($W{\cdot}m^2$). As a magnitude of the1-day or 10-day soil heat flux the grass reference surface is relatively small (Jackson et al., 1977, Sequin and Itier, 1983, Carlson and Buffman., 1989). Therefore, soil heat flux is ignored in this study. The estimation of evapotranspiration considers net radiation flux and sensible heat flux.

$$ET_d - Rn_d = -B{\cdot}(Ts_d - Ta_d)$$

where, ET_d is daily evapotranspiration ($mm \cdot day^{-1}$), Rn_d is daily net radiation ($mm \cdot day^{-1}$), Ts_d is daily surface temperature (K), Ta_d is daily air temperature (K) and B_d is the semi-empirical coefficient ($mm \cdot d^{-1} \cdot K^{-1}$).

Input parameter	Net radiation (Rn)			Land surface temperature(Ts)	Air Temperature (Ta)		B-coefficients	
Data	Coms channel	COMS Insolation	SPOT/VGT Albedo	COMS LST	COMS LST	COMS Channel	Surface roughness	SPOT/VGT NDVI

Table 1: **Used input parameter for estimation of NIMR daily actual evapotranspiration.**

To determine the simplified B-coefficients model, the KMA/NIMR set up the MDB over East Asia. MDB is made up of various input parameters by combining the remotely-sensed data and the the ground-based measurement data. Table 1 shows the input parameter used for estimation of NIMR AET. Net radiation (Rn), which arises from the sum of the net short wave and net long wave components, was computed from COMS incoming short wave radiation. Surface albedo were derived from SPOT/VGT imagery. Net longwave radiation is computed by the Stefan-Boltzmann equation. The ground-based measurement data are wind speed (10m), air temperature (2m), relative humidity and precipitation from 687 meteorological Global Telecommunication System (GTS) data in East Asia. An empirical equation of the B-coefficients model for NIMR AET is developed through the relation between (ET_d - Rn_d) and (Ts_d - Ta_d) using the MDB. B-coefficients are computed by surface roughness and NDVI. The algorithm is characterized by a simply simulated aerodynamic resistance, considering a variety of surface roughness lengths in the sensible heat flux and is estimated on the days with clear sky except for the desert and urban areas. The temporal resolution of NIMR AET is 1-day and the spatial resolution is 1 km. The estimation period is from April 2011 (launched COMS satellite) until the present.

VALIDATION WITH FLUX-TOWER OBSERVATION DATA

To evaluate the estimated NIMR AET, we compared it with the flux-tower observation data at the Seolmacheon River and Cheongmicheon River sites. The flux data are KoFlux data. The KoFlux is a Korean network of micrometeorological tower sites in terrestrial ecosystems and is part of AsiaFlux (http://asiaflux.yonsei.ac.kr) and FLUXNET (http://www.fluxnet.ornl.gov/fluxnet/). Table 2 shows the validation data information located at the Seolmacheon site in mixed forest and at the Cheongmicheon in rice paddy. The period is from April 1 to December 31 2011 during 9 months. The flux-tower observation data are mean daily evapotranspiration. The estimated NIMR AET shows seasonal variation to vegetation from growing season to declining season for the two sites.

Site Name	Location Coordinates	Vegetation Type	Elevation	Terrain Type	Climate	Yearly mean Precipitation	Canopy Height
Seolmacheon (south korea)	37° 56' N, 126° 57'E	Mixed Forest	293 m	Complex	Temperate	N/A	15 m
Cheongmicheon (south korea)	37° 9' N, 127° 39'E	Rice Paddy	141 m	Flat	Warm continental Climate	1170 mm (2008)	1 m

Table 2**: Flux-tower observation data information.**

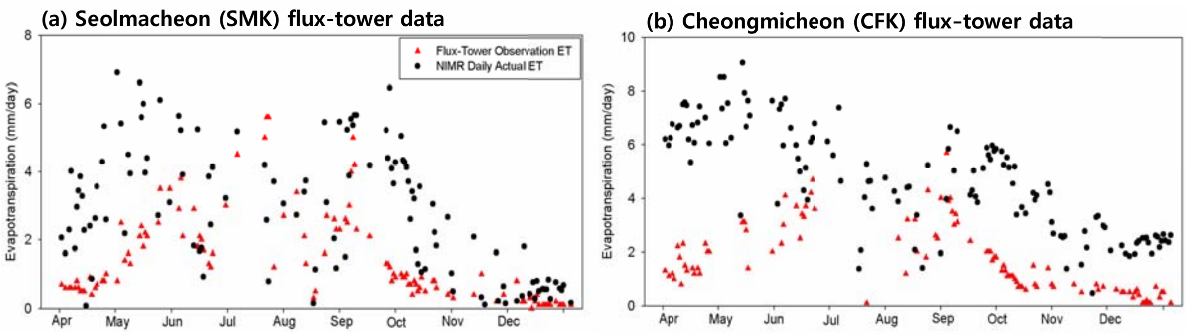

Figure 1: **Time series of comparison with the flux-tower observation data (the red triangular point) ((a) the Seolmacheon flux-tower site (b) Cheongmicheon flux-tower site) with NIMR daily actual evapotranspiration (the black point).**

As a result, the estimated NIMR AET is higher than the flux-tower observation data in the spring and autumn seasons for the two sites, especially at the Cheongmicheon site in rice paddy during spring. Because the NIMR AET pixels do not match the fetch of the flux-tower observation data and the estimated NIMR AET is a remote sensing input parameter compared with the ground-based measurements, remote sensing data still have uncertainties and errors caused by their retrieving algorithm. Hence, the NIMR AET accuracy has included input parameter error and uncertainty. Many of the COMS data products have been updated to new versions with more accuracy.

COMPARISON OF THE NIMR AET WITH MODIS ET PRODUCTS (MOD16 ET)

We produced monthly averaged actual evapotranspiration from April 2011 to January 2012 to evaluate the NIMR AET. The MODIS Global Evapotranspiration (MOD16) algorithm is based on the potential ET with the Penman-Monteith equation (Monteith, 1965) and the MOD16 global ET datasets are regular 1-km^2 land surface ET data sets at 8-day, monthly and annual intervals. The monthly MODIS ET products from April 2011 to January 2012 over East Asia were used in this study (http://www.ntsg.umt.edu/project/mod16). The NIMR AET showed the variation of the season, reflecting the vegetation growth and decline based on each season. The mean monthly NIMR AET is higher than the MODIS ET but is lower than the MODIS potential ET. This difference occurs because the NIMR AET is estimated in the afternoon when the temperature difference between the land surface and atmosphere is high. The NIMR AET is compared with mean monthly MODIS ET. Except during the summer, overall MODIS ET is underestimated over East Asia.

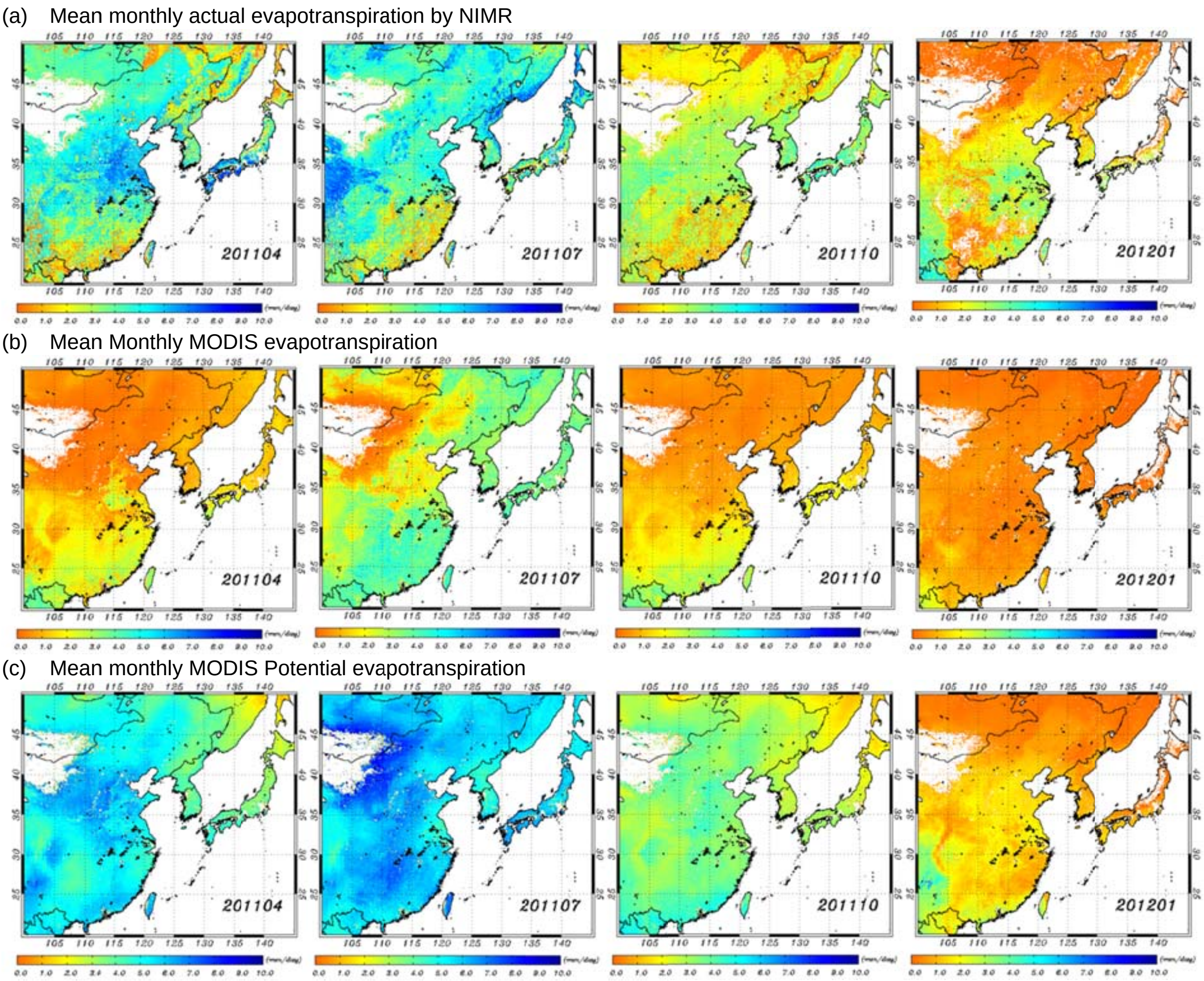

Figure 2: **Comparisons of (a) mean monthly actual evapotranspiration by NIMR and (b) mean monthly MODIS evapotranspiration and potential evapotranspiration from April 2011 to March 2012. (Those seasonally representative months were selected in this figure).**

Because MODIS ET is validated for the American continent, it does not consider regional characteristics. The NIMR AET is compared with the mean monthly MODIS potential ET. The result shows the NIMR AET is similar to the MODIS potential ET, except during the summer months.

SUMMARY

In this study, the KMA/NIMR has improved the NIMR AET over East Asia using a spatio-temporal collocated match-up database by combining remote sensing data and ground-based meteorological data over the region. The advantage of this algorithm is that it can show actual evapotranspiration using satellite data only. The NIMR AET shows relatively high agreement with the flux-tower observation data in mixed forest and the NIMR AET is similar to the MODIS potential ET, except during the summer months. On the other hand, the MODIS ET shows underestimated values compared with the NIMR AET. The estimated NIMR AET is good reflection the regional environment (temperature, land surface temperature, net radiation, and vegetation) of East Asia.

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ACKNOWLEDGEMENTS

This work was supported by the “Research for the Meteorological and Earthquake Observation Technology and Its Application (Ⅰ)” (NIMR-2012-B-3) of the National Institute of Meteorological Research (NIMR), KMA, Republic of Korea.

The Flux-Tower observation data were provided by the Hydrological Survey Center in the Ministry of Land, Infrastructure and Transport.