Downward longwave radiation retrieved from MODIS imagery and possible application on water resource management at Turkey Creek Watershed in South Carolina

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Evapotranspiration (ET) is a critical component to understand the surface energy budget. Accurate estimation of ET using reliable downwelling longwave radiation values may contribute to a better understanding of the surface energy budget, and water resources management at a watershed scale. Point-based ET estimation is not a realistic approach for larger scale watershed management due to its spatiotemporal heterogeneity, and remote sensing technique is a powerful tool to solve this problem. The main objectives of this study are 1) to investigate the most suitable longwave radiation equation for clear sky condition among five well-known equations from literature and ground measured data, and 2) to validate these models with Moderate Resolution Imaging Spectroradiometer (MODIS)-retrieved downward longwave radiation in clear sky conditions. MODIS atmospheric profile products (MOD07/MYD07) were used to estimate MODIS-based downward longwave radiation.

The general form of \( R_{ldc} \) equation is

\[
R_{ldc} = \varepsilon_a \sigma T_a^4
\]

Where, \( \varepsilon_a \) is the atmospheric emissivity, \( \sigma \) is the Stefan-Boltzman constant (W/m\(^2\)/K\(^4\)), and \( T_a \) is the air temperature (K).

The surface emissivity is typically estimated as a function of the air temperature and actual vapor pressure \( (e_a) \). Relative humidity \( (RH) \) and \( T_a \) are measured at the national weather stations in Korea. Based on Relative Humidity \( (RH) \), actual vapor pressure \( (e_a) \) was calculated by the Clausius-Clapeyron equation (Tang and Li, 2008) shown below.

\[
RH = \frac{e_a}{e_s} * 100
\]

\[
e_a = RH* \frac{e_s}{100}
\]

\[
e_s = 6.11* e^{(Lv/Rv)((1/273.15) - (1/ T_a))}
\]

where

\( e_s \) is the saturation vapor pressure in Pa

\( Lv \) is the latent heat of vaporization = 2.45 \times 10^6 \text{ J kg}^{-1}

\( Rv \) is the gas constant for water vapor = 461 \text{ J kg}^{-1} \text{ K}^{-1}

\( e \) is the base of the natural logarithms
Five equations calculating downward longwave radiation ($R_{ldc}$) were selected and compared in this study (Table 1). Ground measured parameters of these equations from four flux towers in South Korea in 2007 were used for calculating $R_{ldc}$. Furthermore, the parameters of these models were retrieved from Moderate Resolution Imaging Spectroradiometer (MODIS). In order to calculate longwave radiation, dew point temperature retrieved from MODIS was used, and Clausius-Clapeyron equation was slightly modified.

$$E_0 = 6.11 \times \text{EXP}(19.59 \times (T_d - 273.3)/ T_d) ;$$

Where, $E_0$ is MODIS-driven actual water vapor pressure at screen level, $T_d$ is dew point temperature.

MODIS retrieved $R_{ldc}$ results were compared with ground measured longwave radiation. Our preliminary results indicated that Brutsaert’s equation (1975) is more accurate than other equations in four flux tower locations in Korea.

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<th>Clear Sky Longwave Radiation</th>
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<tr>
<td>$R_{ldc} = (a_1 + b_1 e^{a_1/2}) \frac{\sigma T_a^4}{T_d}$</td>
<td>$a_1 = 0.605, b_1 = 0.048$</td>
<td>Brunt, 1932</td>
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<td>$R_{ldc} = (1 - a_2 \exp(-b_2(273-T_a)^2)) \frac{\sigma T_a^4}{T_d}$</td>
<td>$a_2 = 0.26, b_2 = 7.77 \times 10^{-4}$</td>
<td>Idso and Jackson, 1969</td>
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<td>$R_{ldc} = a_3 (e^a T_a)^{b_3} \frac{\sigma T_a^4}{T_d}$</td>
<td>$a_3 = 1.24, b_3 = 0.14$</td>
<td>Brutsaert, 1975</td>
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<td>$R_{ldc} = {a_4(1-\exp(-e^{(Ta/b4)})} \frac{\sigma T_a^4}{T_d}$</td>
<td>$a_4 = 1.08, b_4 = 2016$</td>
<td>Satterlund, 1979</td>
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<td>$R_{ldc} = {1-(1 + a_5(e^a/ T_a))\exp(-(b_5 + a_5 c_5(e^a/ T_a))1/2)} \frac{\sigma T_a^4}{T_d}$</td>
<td>$a_5 = 46.5, b_5 = 1.20, c_5 = 3.0$</td>
<td>Prata, 1996</td>
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This is an ongoing study to develop a satellite image-driven ET algorithm on the basis of the climate and topography in the Korean peninsula. The global MOD16 ET product will also be used as a baseline ET estimates. We believe accurate ET estimation is useful and necessary to establish an integrated water resource management system against possible extreme events due to climate change. Such techniques can also be valuable tools for assessing ET and water budget estimates for forested landscapes in the coastal regions of US where rapid development and urbanization is occurring with potential implications to coastal water resources. For example, current ongoing research efforts on assessing hydrology, water quantity and management and potential effects of land use and climate change on them at Santee Experimental Forest including Turkey Creek watershed as reference systems within the USDA Forest Service Francis Marion National Forest near Charleston, South Carolina can be complemented with these new techniques for estimates of ET, which is a challenge for the complex forest ecosystems.