Seasonal Net radiation (Rn) characterization and its response to landuse/cover in Northeast China

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The net radiation (R_n) affects the energy sink lost to the atmosphere through radiative process, which is the driving force for the surface energy balance and vitally important for various applications, including climate studies, agricultural meteorology and hydrological process as well. The R_n is defined as the difference between the incoming and outgoing radiation fluxes including both longwave and shortwave radiation at the surface of the earth. Remote sensing provides an unparalleled spatial and temporal coverage of land surface attributes, thus several studies have attempted to estimate net radiation by combining remote sensing acquired measurements with surface and atmospheric data (Diak and Gautier, 1983, Jacobs et., 2000; Ma et al., 2002). R_n, coupled with soil heat flux and sensible heat flux, serves as a key driving force for the evapotranspiration (ET). Several ET estimation models based upon remotely sensed data and ancillary surface and ground-based observations over the past years.

Estimating $R_{n,}$ the land surface temperature is commonly obtained directly from remote sensing observation, generally by using the split-window technique (Becker and Li, 1990). Whilst, the other components for deriving R_n, such as land surface albedo, land surface emissivity, air temperature, air emissivity and incoming shortwave radiation usually obtain from radiative transfer models, ancillary ground measurement or assumptions about certain parameters. R_n is a land surface parameter depending on solar elevation, gelocations, land surface characterization and its seasonal variation. Traditional methods for estimation R_n at the land surface can be expressed in terms of its components as

$$R_n = R_S{}^{\downarrow} - R_S{}^{\uparrow} + R_L{}^{\downarrow} - R_L{}^{\uparrow} \tag{1}$$

Where $R_S{}^{\downarrow}$ and $R_S{}^{\uparrow}$ are shortwave radiation fluxes downward (W・m^{-2}) and upward (W・m^{-2}), respectively and $R_L{}^{\downarrow}$ and $R_L{}^{\uparrow}$ are longwave radiation fluxes downward (W・m^{-2}) and upward (W・m^{-2}), respectively. The shortwave radiation can be expressed as

$$R_S{}^{\downarrow} - R_S{}^{\uparrow} = (1-\alpha)\times R_S{}^{\downarrow} \tag{2}$$

Where α is land surface reflective albedo. In essence, downward shortwave radiation can be expressed as

$$R_S{}^{\downarrow} = S_0 \tau_{sw} \cos\theta \tag{3}$$

Where τ_{sw} is the atmospheric clear sky shortwave transmission factor, S_0 is the solar constant at the atmospheric top, which is about 1367 W m^{-2} and θ is the solar zenith angle. In this study, the longwave radiation can be expressed using the Steffen-Boltzmann equation as

$$R_L^{\downarrow} - R_L^{\uparrow} = \sigma\varepsilon_a T_a^4 - \sigma\varepsilon_s T_s^4 \quad (4)$$

Where ε_a is air emmisivity, ε_s is surface emissivity, T_a is air temperature (Kelvin) at screen level, T_s is land surface temperature (Kelvin) and σ =5.67*10^{-8} W m^{-2} K^{-4} is the Steffen-Boltzmann constant.

In this paper, the simple method mentioned above was applied to estimate instantaneous and daily Net Radiation over large heterogeneous areas for clear sky days using remotely sensed MODIS data and climatic station observed data over Heilongjiang Basin (about 2,100,213km^2) in 2007. Seasonal R_n trend was analyzed according to land use/cover characterization that not only affecting albedo feature, but also land surface solar flux absorption features, which determine the final R_n over large area for different seasons. Our results indicate that the minimum instantaneous and daily R_n value for the Heilongjiang Basin is about -5.17 W • m^{-2} and -68.47 W • m^{-2} in January 17^{th} of 2007, respectively, which happens at the estuary of Heilongjiang River to the Dadan Sea. But our result only estimate the overpass time with less cloud contamination weather conditions, the actually minimum instantaneous and daily R_n value may even lower during the coldest month of the region. While the maximum instantaneous and daily R_n value for the Basin are about 353.8 W • m^{-2} and 7.15 W • m^{-2} for the same data, and high R_n values happens at southern part of the Songnen Plain and eastern part of Changbai Mountain. The average instantaneous and daily R_n value for the whole basin is about 109.5 W • m^{-2} and -39.41 W • m^{-2} in January 17^{th} of 2001. The average instantaneous R_n changes from 109.5 W •m^{-2} in January to 161.13 W •m^{-2}, 249.65 W •m^{-2}, 312.89 W • m^{-2}, 560.036W • m^{-2}, 604.27W • m^{-2}, 584.78 W • m^{-2}, 498.89W • m^{-2}, 292.572 W • m^{-2}, 297.88W • m^{-2}, 205.99W • m^{-2}, 119.74 W • m^{-2}, respectively from February to December. Whilst , the daily R_n changes from February to December ranging from -13.09 W •m^{-2}, 3.74 W •m^{-2}, 147.56 W •m^{-2}, 211.89 W •m^{-2}, 237.41 W •m^{-2}, 225 W •m^{-2}, 183.74 W •m^{-2}, 116.65 W •m^{-2}, 43.723 W •m^{-2}, -4.54 W • m^{-2}, -36.125 W • m^{-2}, respectively for a specific day during a month. Due to cloud contamination, there are less qualified LST MODIS products for R_n estimation during some specific month, which may affect the statistical trend of instantaneous and daily R_n values of the region. Our result also indicates that albedo have a great influence on the R_n budget for the region, especially when the region is covered with snow that usually result in high albedo of the land surface with low daily R_n. With spatial analysis, the result shows that minus daily Rn value has a consistent pattern with snow covered area of the region. Also land cover exert a significant influence on the R_n pattern over the region due to its effect on the albedo, soil moisture, and evapotranspiration condition that effect the solar engery absorption characterization over large area. Our preliminary result still need a lot refined analysis and ground truth data to calibrate in the future work, especially the response of R_n change to land cover characterization and its seasonal variation due to ecosystem phonological change..

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