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Greenland surface net radiation estimation using MODIS data

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In recent decades, the Greenland ice sheet has undergone massive melting events, which played a crucial role in regional climate change and global sea level rise. Changes in surface energy budget (SEB) is one of the driving forces that determined ice sheet mass balance. Surface net radiation variation is an important proxy to assess the SEB. Due to the limited number of radiation measurement sites, the spatial and temporal variation of net radiation has not been fully understood. Satellite remote sensing has the ability to retrieve net radiation with a better spatial and temporal coverage as well as reasonable accuracy. Existing satellite products, such as the Clouds and the Earth's Radiant Energy System (CERES) data, provide monthly net radiation at a 1-degree resolution, which is insufficient for SEB analysis over the Greenland, particularly for the ablation zone. The Global Land Surface Satellite (GLASS) products provide daytime average net radiation at a 0.05-degree resolution with accuracy comparable to the CERES product on the global basis. However, the GLASS product is only available during the daytime when the input of surface downward shortwave radiation estimation is available, which significantly limited the use of GLASS net radiation product over polar regions. To solve these issues, in the present study, we developed an empirical approach via machine learning algorithms to derive all-sky surface net radiation over the Greenland. GC-Net measurements and top-of-atmosphere reflectance of Moderate Resolution Imaging Spectroradiometer (MODIS) were matched to build a dataset for models calibration and validation. Among several machine learning algorithms, the artificial neural network algorithm provided better estimation than support vector machine and random forest algorithms, with an R of 0.90, a bias of 0.77 W/m2, and a root-mean-square-error (RMSE) of 47.19 W/m2 for instantaneous all-sky daytime net radiation estimation and an R of 0.52, a bias of -0.61 W/m2, and an RMSE of 19.02 W/m2 for instantaneous all-sky nighttime net radiation estimation. The new models provided better accuracy than existing satellite products over the Greenland. More importantly, our net radiation estimates have a spatial resolution of 1km and the approach requires few ancillary inputs. However, more efforts are still needed to improve the all-sky net radiation estimation during nighttime under cloudy conditions and to understand the diurnal cycle of net radiation. Nevertheless, the developed model with improved net radiation estimates showed promise for producing time series product from MODIS data so that snow mass balance under the changing climate could be better understood over the Greenland.