Robustness of optical remote sensing of cloud by deep convolutional neural network using multi-channel imaging spectroradiometer

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Deep neural networks (DNNs) have recently been used in many problems of remote sensing. We have applied the DNNs to optical remote sensing of cloud from satellite- and ground-based imagers, for which the DNNs have been trained by a radiative transfer model (physics model). In optical remote sensing, three-dimensional (3D) radiative transfer effects significantly influence the cloud property retrieval from high-resolution optical instruments, operating across spatial elements of the cloudy atmosphere at a wide range of spatial scales. Because multispectral images contain spectral and spatial features, convolutional neural networks (CNNs) naturally trace the 3D radiative effects that appear across image pixels, which traditional single-pixel approaches cannot capture. Training data of synthetic radiances are made from simulations using a Monte Carlo 3D radiative transfer model for cloud fields simulated by a large eddy simulation model. The DNN can represent the cloud structure and 3D radiative effects that depend on many factors including sun-cloud-view geometry, cloud structure, aerosols, and surface reflection. Because satellite observation usually provide useful metadata information such as solar and satellite geometrical parameters, aerosol state, and surface reflectance, we have recently developed a new DNN architecture that is suitable for multimodal fusion of image and metadata. Furthermore, we found a way to properly treat measurement noise and bias in the DNN. If a DNN is trained on datasets of multispectral images with synthetic noise and bias of appropriate magnitude, cloud retrieval by the DNN is robust, not strongly depending on the absolute calibration and noise of instrument. If measured radiances are more uncertain, the DNN becomes to more strongly rely spatial features to estimate the cloud properties. We will show the robustness and sensitivity to noise and bias.

Keywords: remote sensing, cloud, deep neural network

