Attention-Enhanced Deep Learning Framework with Edge-Aware Preprocessing for Ground-Based Cloud Classification

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Abstract. In weather forecasting, aviation safety, and climate-related decision-making a vital role is being played by cloud classification. Traditional methods, which often depend on manual observation or handcrafted features, tend to fall short under diverse atmospheric conditions. In response, this work explores many approach which are established on deep learning to automate many type of cloud classification from ground-based imagery. The model is based on a Convolutional Neural Network (CNN) architecture, enhanced with edge-sensitive preprocessing and attention modules to more accurately represent the complex structures of various cloud formations. A publicly available, multi-class cloud image dataset is used for training and evaluation, with extensive data augmentation applied to improve robustness. Experimental results indicate significant improvements in classification accuracy with 92%, consistency across cloud types, and class separability when compared to conventional baselines. The model demonstrates potential for reliable performance in operational meteorological systems. These findings highlight the effectiveness of integrating domain-specific preprocessing and attention mechanisms within deep learning pipelines for cloud each classification tasks.

Keywords: Cloud classification · deep learning · convolutional neural networks · ground-based cloud imagery · attention-based feature learning

1 Introduction

Cloud classification is a process of identifying and categorizing clouds based on visual features like structure, shape and altitude. It is a fundamental aspect of meteorology, as different cloud types are closely linked to specific atmosphere and weather events. For example, cumulonimbus clouds are often associated with

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