ISARD-2025-satellite005

Nowcasting of cloud motion using Himawari-9 satellite data with a combined neural network approach

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Nowcasting of cloud motion represents a significant area of modern meteorology, with the primary task being the analysis of changes in cloud cover over time intervals ranging from several minutes to several hours. This capability is crucial for various applied tasks, such as forecasting convective processes, analyzing hazardous atmospheric phenomena (e.g., thunderstorms, squalls, or heavy rainfall), ensuring aviation safety, optimizing agricultural operations, and planning the operation of solar panels. The development of effective nowcasting methods that enhance accuracy and lead time has become an integral part of scientific research in meteorology. Various approaches are employed to implement nowcasting, including those based on numerical weather forecast models, as well as algorithms based on satellite image analysis. Predictive models provide high accuracy but require significant computational resources and extensive input data, making their application resource-intensive and complex. An alternative solution is to use satellite data analysis methods such as optical flow or neural networks. The nowcasting algorithm presented in this paper was developed on the basis of neural networks, which have proven themselves well in the analysis of complex spatiotemporal dependencies. The study was conducted using channel data with a central wavelength of 11.2 μm from the AHI (Advanced Himawari Imager) instrument installed on the Himawari-8/9 spacecraft, which allows obtaining images in the visible and infrared range with a spatial resolution of 2 km. The developed algorithm is a combined approach based on the use of two sciencasting models adapted to solve the problems of forecasting the movement and evolution of clouds. The proposed approach is based on the NowcastNet architecture, designed to predict precipitation. The generator block taken from this model has been supplemented with a module that allows taking into account the influence of the underlying surface. The generator was trained as a deterministic model that is able to provide the most accurate prediction of the direction of movement of objects and their intensity. However, due to the averaging of the output data, this approach can lead to blurring of the predicted cloud formations. To improve the quality of the forecast, the second part of the algorithm was added, based on the CasFormer model. This diffusion statistical model is used to post-process forecast results in order to improve the detail, contrast, and overall perception of images. Thus, the combination of a deterministic generator and a statistical model made it possible to achieve high forecast accuracy, while preserving the details of cloud structures. The developed algorithm makes it possible to forecast cloud movement for up to 3 hours with an interval of 10 minutes. Quality assessment of the algorithm revealed that, on average, the RMSE (Root Mean Squared Error) metric was approximately 7 K, SSIM (Structural Similarity Index) reached 0,75, and PSNR (Peak Signal-to-Noise Ratio) was 27,1 across all images.

This research has been supported by:

1. "Russian Science Foundation", grant 23-77-00011