Short-Term Precipitation Forecasting from Satellite Data Using Machine Learning

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Introduction

Predicting short-term precipitation is pivotal for various applications, yet current methods primarily rely on ground weather radars, which have limited coverage. Geostationary meteorological satellites offer global and frequent observations, but do not directly measure precipitation. Addressing this gap, the thesis aims to develop a deep learning approach to predict precipitation using only satellite radiance images.

Data

To train and test our method on real-world data, we participated in the NeurIPS Weather4cast 2022 competition, which provides spatially and temporally aligned satellite and precipitation radar images. The data are sourced from 7 European regions, spanning two years. The satellite frames consist of 11 spectral channels at a spatial resolution of 12 km per pixel. The target radar frames cover a 6 times smaller area (placed at the center of the satellite frame) at a 2 km per pixel resolution.

The task of this competition was to develop a model to predict radar frames up to 8 hours to the future from 1 hour of satellite input. Both sequences have a spatial resolution of 15 minutes, totaling 4 input frames and 32 output frames. The target has been simplified to binary classification (rain or no rain) with a threshold of 0.2 mm/h.

WeatherFusionNet

The thesis introduces a novel method for this task. It utilizes the U-Net [4] and PhyDNet [2] convolutional neural networks. It was named *WeatherFusionNet*, as it fuses three different ways to process the satellite data; predicting future satellite images, detecting precipitation in the input sequence, and using the input sequence directly. As shown in Figure 1, this is realized by three neural networks, which are trained separately. *Satellite PhyDNet* is trained to predict the future satellite sequence, *Sat2Rad U-Net* is trained to detect precipitation in a single satellite frame. The outputs from these two modules are then fused along with the input sequence by another U-Net. The final output is cropped and upscaled to match the target area and resolution.

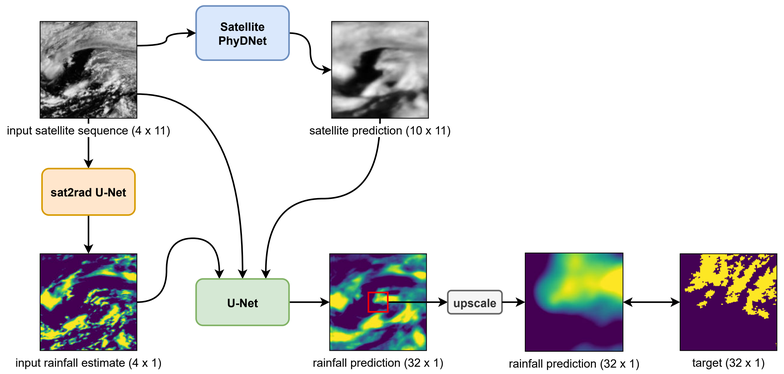

Figure 1. Illustration of WeatherFusionNet training architecture. The dimensions in parentheses denote the temporal and channel dimension sizes, respectively.

Results

WeatherFusionNet achieved 1st place in the Core challenge of the NeurIPS Weather4cast 2022 competition. It also placed 3rd in the Transfer challenge, which tested models on data from different regions and/or time periods.

The thesis further includes empirical results, comparisons with different approaches, as well as an ablation study, experiments with model variations and comparison with a direct radar-to-radar model. An example prediction of *Sat2Rad U-Net* is shown in Figure 2.

Contribution highlights

As a submission to the competition, an extended scientific abstract [3] was published. It was highlighted in the proceedings of the competition [1]. Additionally, an article for a top-tier journal is currently in preparation.

The code for our competition submission is open-source, available here, and the source code of the thesis is available here.

The method was developed as part of an ongoing research project in collaboration with Meteopress, which has taken interest in implementing it in production.

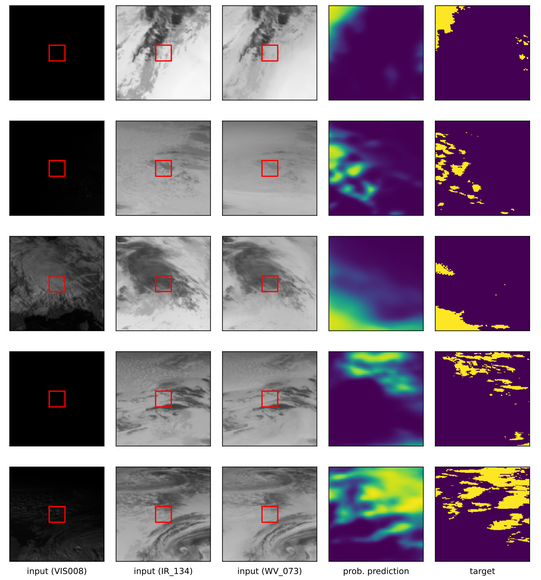

Figure 2. *Sat2Rad U-Net* example predictions. Each row is a different sample. First three columns are selected input channels. Red squares highlight the target area. Fourth column shows the raw probability output of Sat2Rad, before applying a threshold. Final column is the binary target, where yellow highlights rain, purple means no rain (0.2 mm/h threshold).

References

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