

Satellite–Radar Fusion for Operational Precipitation Analysis Using Deep Learning

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SMHI has recently improved its system for precipitation monitoring. The system now includes a trained machine learning (ML) model that every 15 minutes estimates the present near-surface precipitation from geostationary satellite based observations. This estimate is merged with the estimate from the ground based radar network, resulting in a significant improvement compared to the purely radar based analysis used previously. The result is propagated forward in time, using an optimal flow technique, to obtain a short-range precipitation forecast, available to users through the SMHI app and webpage. This talk focuses on describing the data and methodology used to train and evaluate the performance of the ML model, including a lean workflow SMHI has developed to allow for a close to continuous deployment of re-trained and improved versions of the ML model.

The ML model framework, CHIMP (Chalmers/CSU Integrated Multi-Satellite Precipitation retrieval program) has been developed at Chalmers University of Technology. The model applied here uses several Encoder/Decoder stages based on inverted bottleneck blocks with separable convolutions for the channel, spatial, and temporal mixing for an efficiency reason and inspired by EfficientNet-V2 paper: <https://arxiv.org/pdf/2104.00298>.

The latest operational model has been trained on 4 years (2018-2021) of SEVIRI and BALTRAD weather radar data. Training has been done in the European Weather Cloud with radar data as the target. The current trained model takes as input all 12 SEVIRI channels for the last 4 hours (16 SEVIRI slots) and outputs precipitation intensities. The results are verified against three years (2022, 2023, and July 2024 - June 2025) of ground truth data - a 4km and 15-minute resolution gridded dataset of rain gauge observations over Sweden, adjusted using hydrological modelling (PTHBV - reference?).

SMHI has developed a workflow and tools to facilitate re-training, re-processing, verification, and deployment. The verification of a new model is a key aspect, and a management decision score was derived and used to judge if a new version of the model is better than a previous one. Until now most efforts have been put on quality control and filtering of the BALTRAD radar data for improving the model. The strategy has been to only use the best and most reliable radar estimates for the training in order to avoid the model to learn from artefacts in the data.

The new operational precipitation analysis at SMHI, is basically calculated as a weighted average of the estimates from the ML model and the radar network. The weights vary with geolocation and season and are based on the management score. The merging of the two estimates also involves an adjustment to rain gauge data and a bias correction and will be described in more details. Despite a general improvement, there are still significant deficiencies left in the analysis, for instance in the mountain areas and in the north of Sweden. This we plan to address partly by starting using also passive microwave observations from polar orbiting satellites (foremost SNPP/JPSS ATMS and AWS) and partly by starting migrating from SEVIRI to Meteosat-12 FCI, and results from this exercise will be presented.