Towards EUMETSAT MTG Day-2 precipitation rate product: deep learning for precipitation rate retrieval from GEO IR and MW measurements

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EUMETSAT H SAF Goals

- **to provide satellite-derived products from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology; identified products:**
  - **precipitation (liquid, solid, rate, accumulated);**
  - **soil moisture (at large-scale, at local-scale, at surface, in the roots region);**
  - **snow parameters (detection, cover, melting conditions, water equivalent);**
- **to perform independent validation of the products and evaluate their contribution in operational hydrology.**

Aim of this Study

To develop a **combined** infrared-microwave (IR-MW) algorithm, based on a **deep learning** methodology which exploits the multi-spectral IR MSG SEVIRI measurements in order to provide instantaneous precipitation rate at high spatial and temporal resolution. The algorithm is the **baseline** for developing the new release of the **EUMETSAT H SAF day-2 product** for the upcoming MTG Flexible Combined Imager (FCI).

The Problem

PMW radiometeres have **superior capabilities** with respect.to VIS/IR measurements to monitor and estimate precipitation*

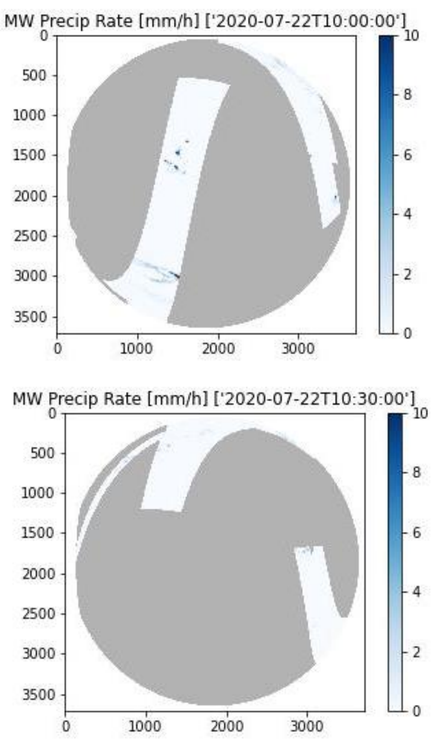
The use of the full constellation of LEO PMW radiometeres, including the future european EPS-SG mission, Is Needed to increase temporal and spatial coverage.

Using all available radiometers we can get a complete measurement of the full globe **every 3 hours**

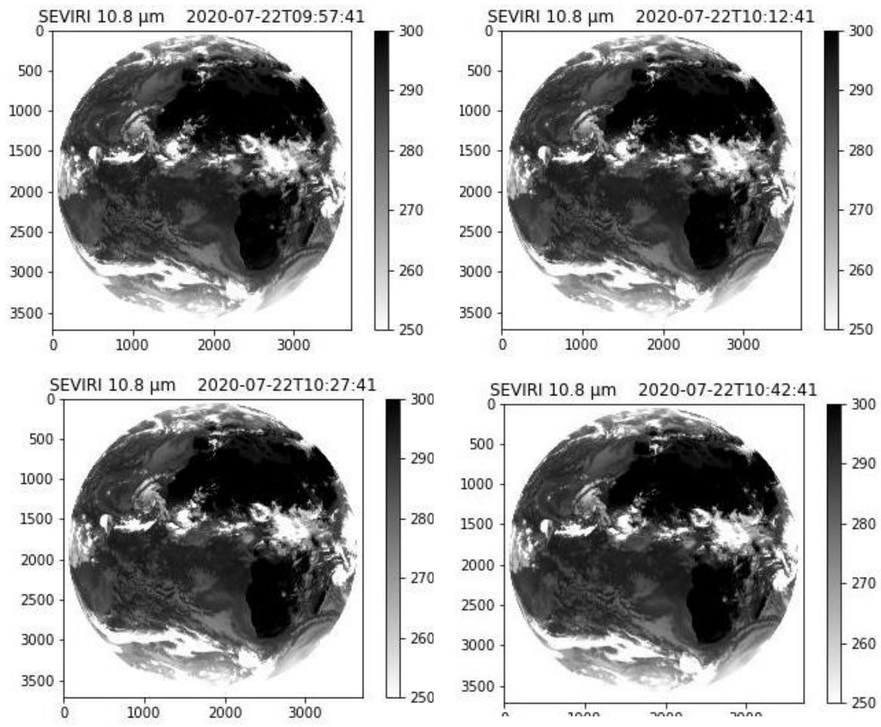
To obtain a precipitation product useful for monitoring purposes the PMW based precipitation must be **merged** with **IR-VIS** observations from geostationary satellites (available every 10-15 minutes)

*see Poster on Thursday: **TA-2** The EUMETSAT EPS-SG MWI and MWS day-1 Machine Learning algorithms for snowfall and rainfall surface precipitation rate retrieval

Composite of all available PMW in 30 minutes



GEO VIS-IR available every 15 minutes (10 minutes with MTG)



Dataset

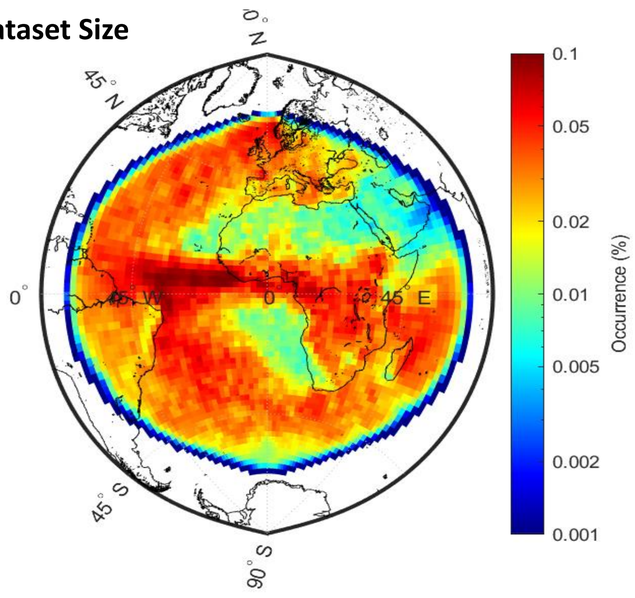
The NASA/JAXA GPM-CO equipped with the DPR and the GMI currently offers the most accurate precipitation estimates and Is used as reference for the development of PMW products

File format: Zarr zip file
Period: 2017-2020
Data included:

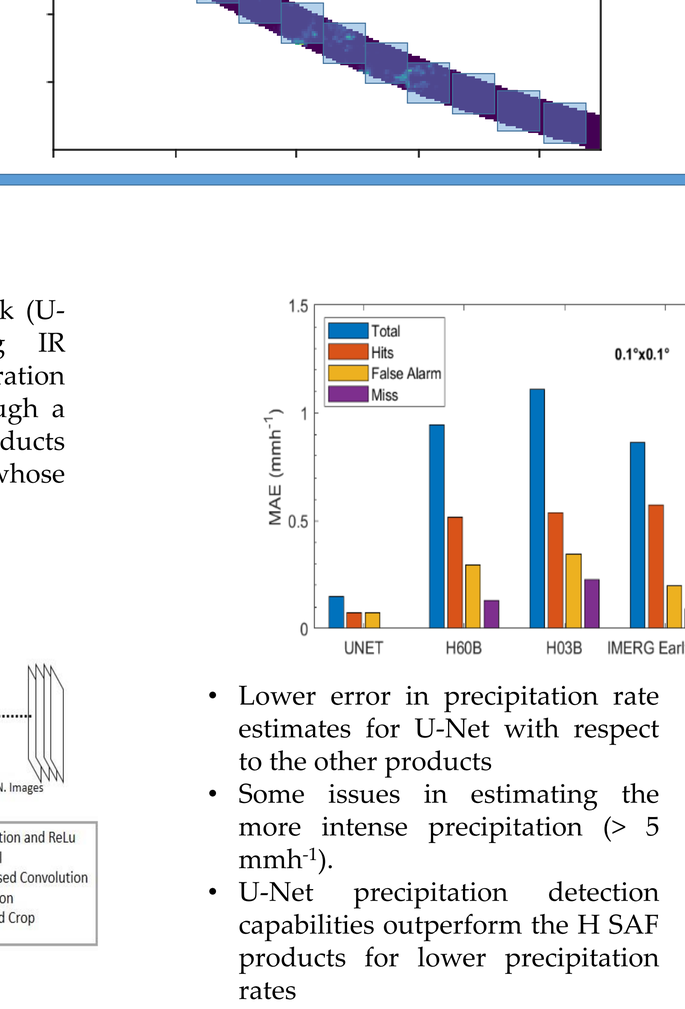
- MSG-SEVIRI (11 channels non normalized float32)
- GPM DPR (Surface Precipitation Rate)
- Ancillary variables (Lat, Lon, View angles, time)

Image size: 64 x 64 pixels

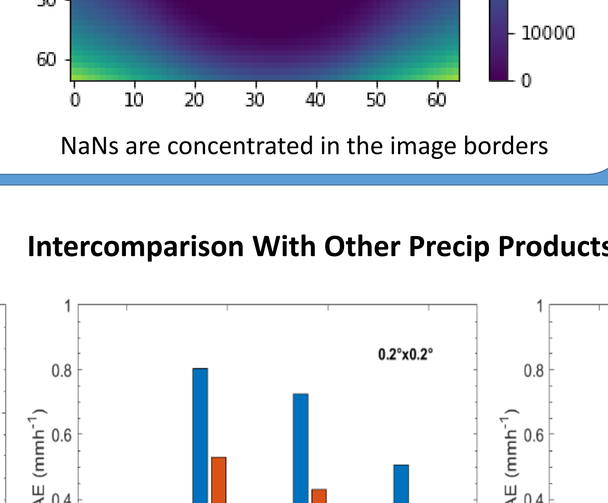
Dataset Size

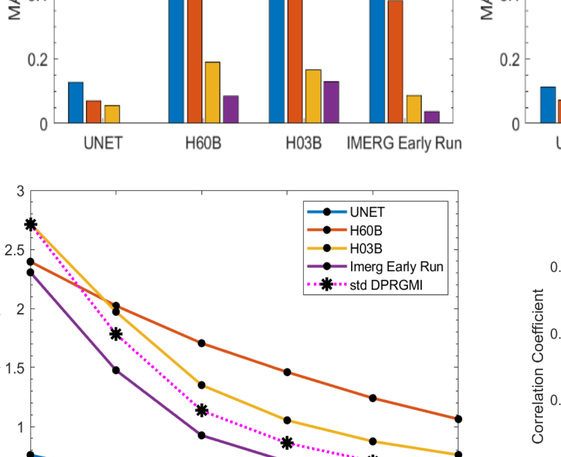


DPR Radar MSG Spatial Matching



Dataset Size and missing values





Existing MW-IR Precip Products:

IMERG: is the main official GPM MW/IR product (NASA), combining geostationary IR and PMW data of the GPM constellation satellites. IMERG processing include (1) CMORPH-Kalman Filter (2) the PERSIANN-CCS for retrieving PMW calibrated IR estimates, and (3) the TRMM Multi-satellite Precipitation Analysis products (TMPA) for inter-satellite calibration and monthly gauge adjustment

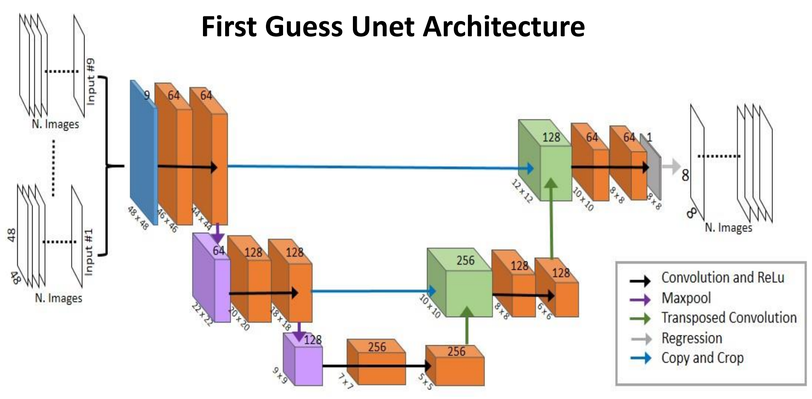
P-IN-SEVIRI H03 is an old product from H SAF based on Rapid Update (RU) blending technique

H60 P-IN-SEVIRI is the most recent H SAF product including H03 and NEFODINA for the enhancement of convective precipitation.

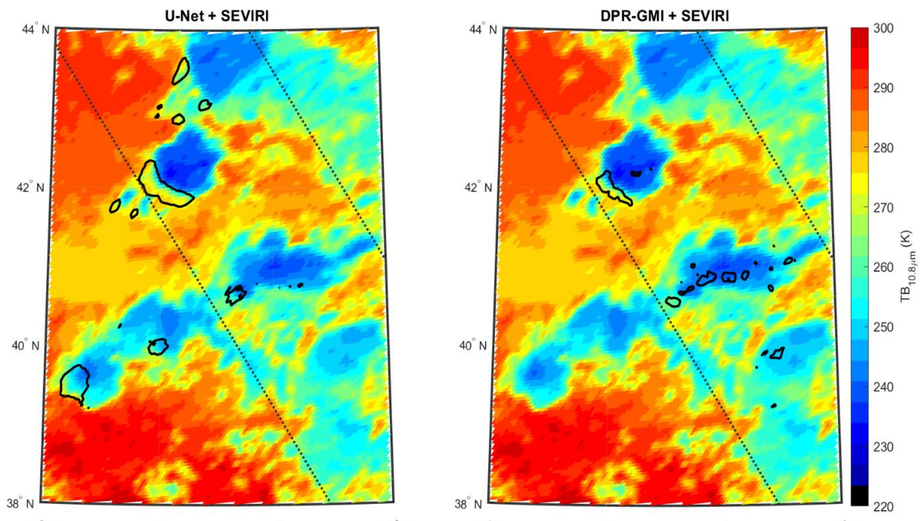
First guess Module

First Guess Module is a convolutional neural network (U-Net) to retrieve the precipitation rate using IR measurements only from the Meteosat Second Generation (MSG) satellite. Its performances are evaluated through a comparison with H SAF and NASA operational products (e.g. H60B or H03B, and IMERG-E, respectively), whose algorithms are based on different principles.

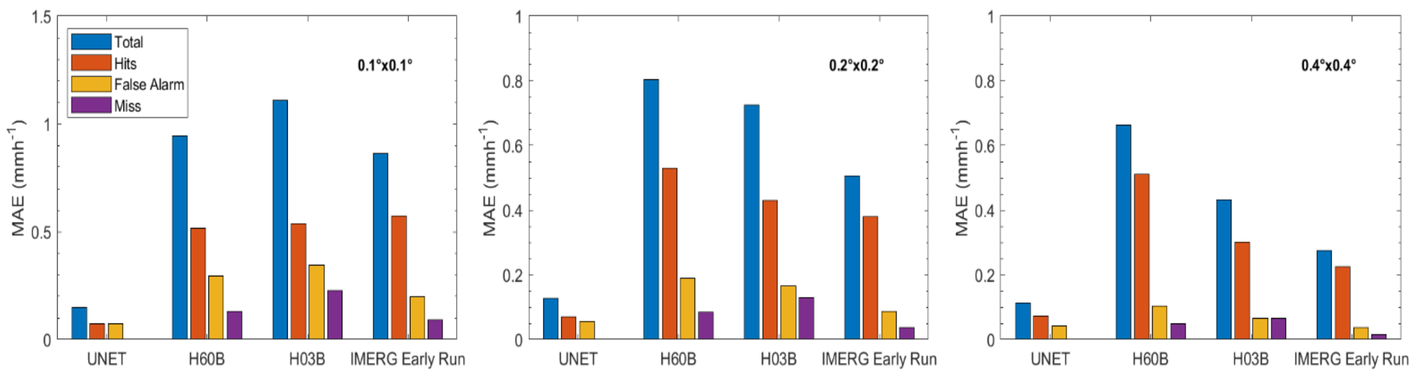
First Guess Unet Architecture



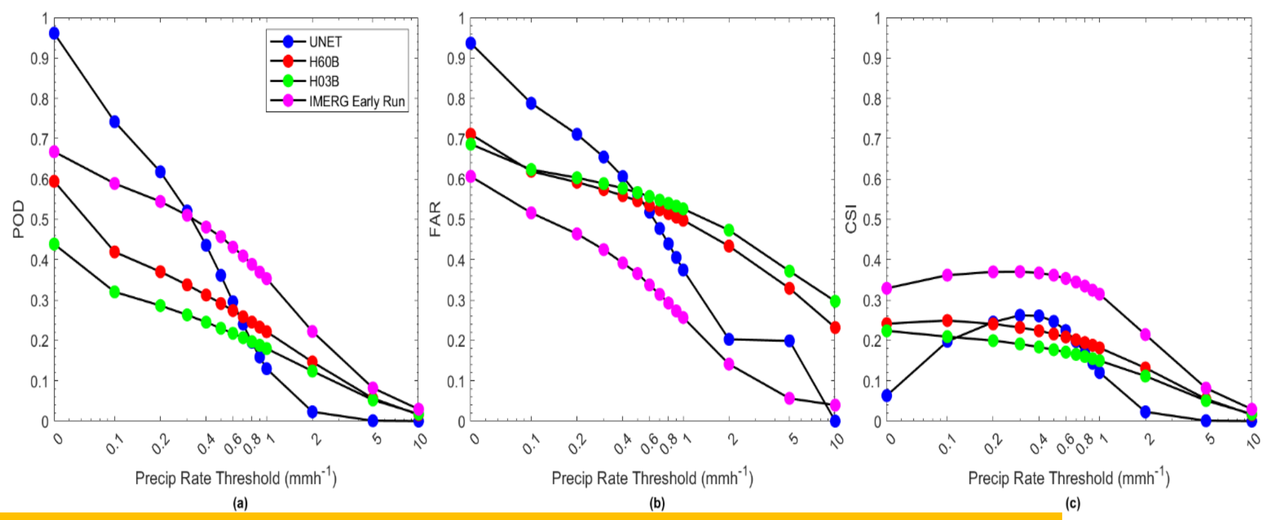
the U-Net is able to account for and correct the parallax displacement



Intercomparison With Other Precip Products



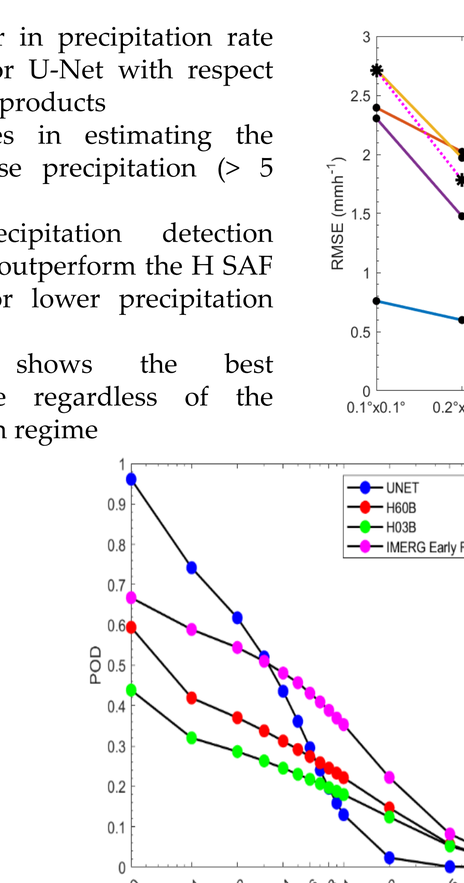
- Lower error in precipitation rate estimates for U-Net with respect to the other products
- Some issues in estimating the more intense precipitation (> 5 mmh^{-1}).
- U-Net precipitation detection capabilities outperform the H SAF products for lower precipitation rates
- IMERG-E shows the best performance regardless of the precipitation regime



D'Adderio, Leo Pio, et al. "A First Step towards Meteosat Third Generation Day-2 Precipitation Rate Product: Deep Learning for Precipitation Rate Retrieval from Geostationary Infrared Measurements." *Remote Sensing* 15.24 (2023): 5662.

MW data fusion Module

to merge the Level 3 PMW precipitation rate product – H68 with the temporal evolution of precipitation patterns provided by the first guess.



Open Issues:

1- DPR radar used as reference precipitation covers a very small section of the SEVIRI full disk. We need to process years of data to get acceptable training DS size.

2- We have some missing data in the reference DPR precipitation -> solved with proper image cropping and use of custom loss function (minor issue)

3- PMW input has many missing values. Hard to deal with convolutions. (major issue)

4- Architecture of the network (now convLSTM) is under investigation

5- PMW data timeliness (data will be fully available about 1 hour after the observation) -> how the network will be able to predict forward in time?

6- PMW data freshness -> how long shall the sequence go in the past?