D3.4 - Operational opportunistic sensing precipitation product available as case study demonstrator for hydrological application

Version 1.0

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About OPENSENSE (COST Action CA20136). *OPENSENSE brings together scientists investigating different opportunistic sensors (e.g. microwave links, citizen science), experts from weather services, and end-users of rainfall products to build a worldwide reference opportunistic sensing community. The overarching goals of the COST are to overcome key barriers preventing data exchange and acceptance as hydrometeorological observations, define*

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standards to allow for large-scale benchmarking of opportunistic sensing precipitation products and develop new methods for precipitation retrieval, coordinate integration of the opportunistic observations into traditional monitoring networks, and identify potential new sources of precipitation observations. Further details can be found here:

Table of contents

Glossary

WG	Working Group
OS	Opportunistic Sensors

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1. Introduction

A main goal of OpenSense was to coordinate the setup of a whole chain from OS data access to a final application that benefits from OS data. Albeit no real-time open access dataset could be set up within OpenSense, there were several case studies that achieved to set up a pipeline from raw data to final hydrometeorological products with some of them also providing these products to the public. This documents collects information on these case studies from Germany, Sweden and France and gives an outlook on ongoing activities on European level at Eumtnet, that OpenSense coil accelerate.

2. Case study in Germany - The HoWaPRO project

At the German Weather Service (DWD), CML data was used to adjust weather radar data in a semi-operational manner between June 2023 until Spring 2025. This project is called HoWa-PRO and several members of OpenSense were actively participating in that project, namely Tanja Winterrath (DWD), Christian Chwala (KIT) and Maximilian Graf (University of Augsburg, later DWD).

The overarching goal of the project was to enable timely flood warnings in small catchments using innovative precipitation products derived from the merging of weather radar and commercial microwave link (CML) data (Winterrath et al. 2025).. Real-time CML data was provided by Ericsson in a cloud-based storage system and processed at DWD. The average latency for a 99% CML data availability was approximately 2.5 minutes.

The technical setup of the software infrastructure was relatively straightforward compared to the legal challenges that had to be resolved between the legal departments of the University of Augsburg and Ericsson. The negotiations mainly focused on establishing a non-disclosure agreement (NDA), where significant effort was required to explain the kind of data that was to be used and thus, to define the scope of the protected data.

At DWD, data from several thousand CMLs were utilized to adjust the national radar composite over Germany (RADOLAN-RY) using the newly developed adjustment software pyRADMAN. The system is capable of pre-processing CML data and adjusting radar-based precipitation estimates using either rain gauges, CMLs, or a combination of both as reference sensors. Furthermore, pyRADMAN allows adjustments at different temporal aggregations, ranging from 60-minute to 15-minute intervals. The resulting precipitation products were visualized in real time on the HOWA-PRO demonstrator (in German), together with the outputs of a flood forecasting system driven by the CML-gauge-adjusted product (https://howapro.de/). The flood forecast was only activated when predefined thresholds were exceeded.

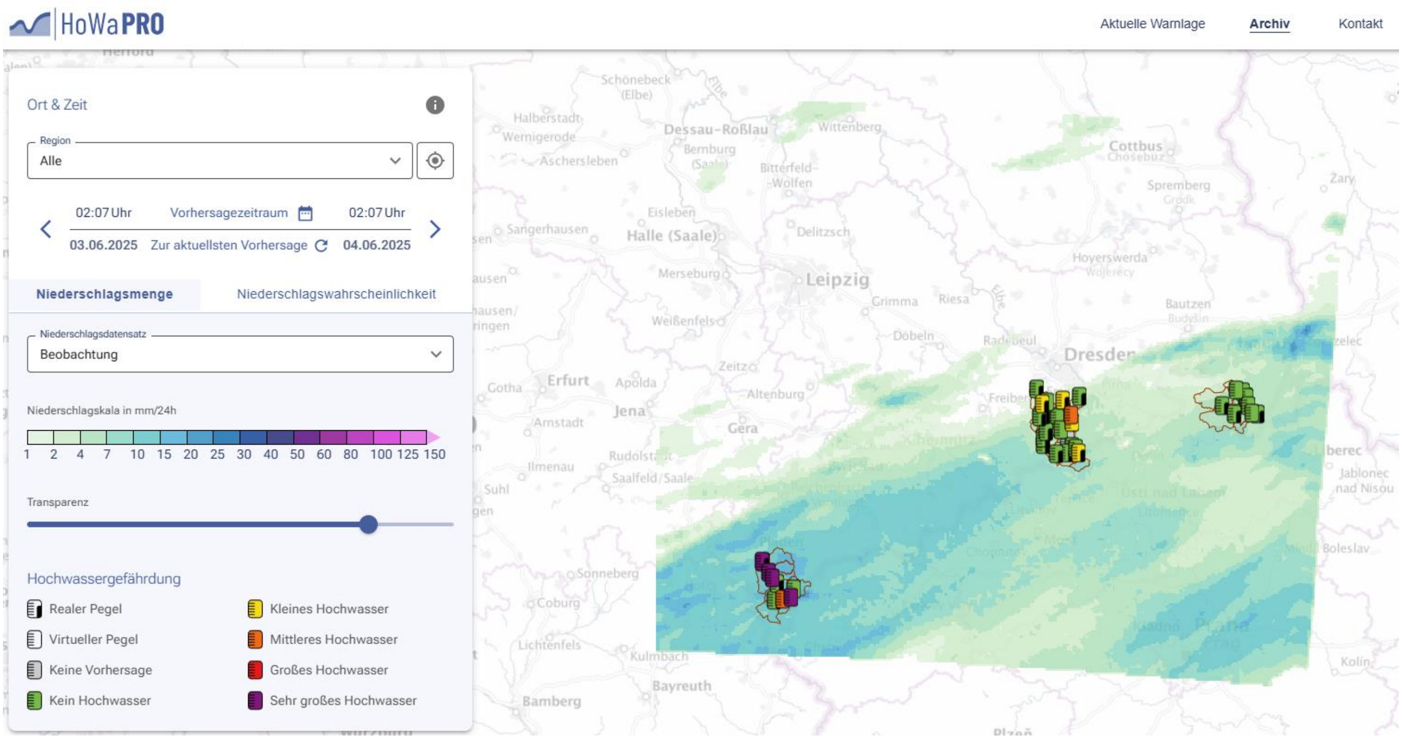

Fig. 1 Accumulation of the last 24 based on a combination of radar, gauge and CML data for the south of Saxony, Germany. The stream-flow gauges in the three test regions are colorized based on results of a flood forecasting system that uses the observed rainfall data as well as forecasted precipitation data from DWD's ICON model.

After the project ended, the data delivery from Ercisson was stopped and, because Ericsson is running its CMLs for mobile network operators, there is no clear agenda to continue the delivery.

OpenSense contributed to the project in multiple ways. On the data and software side, dataset conventions proposed by *Fencl et al. (2024)* were adopted, and components of the adjustment software were integrated into the mergeplg tool (https://github.com/OpenSenseAction/mergeplg), which now can be reimplemented into DWDs software framework utilizing more adjustment methods from the OpenSense community. In addition, OpenSense served as a platform for exchange on legal, technical, and scientific aspects during the development of the new adjusted products.

3. Case studies in Sweden - PWS and MEMO

3.1. PWS at SMHI

At SMHI, the possibility to use PWS data for operational meteorology and hydrology has been investigated for around 5 years. Initial work focused on temperature but with time more and more attention has been put on precipitation or, more specifically, rainfall. Promising results from case studies covering different locations (cities) and (pluvial flood) events generated an interest in investigating the potential to integrate PWS in operational systems and products.

Currently (autumn 2025), work is ongoing in two separate (but related) tracks. In the national track, PWS data are integrated with observations from satellites, C-band weather radar composites and the national network of meteorological stations to produce national gridded precipitation on 2×2 km² spatial resolution and potentially sub-hourly temporal resolution. In the local/urban track, PWS data are integrated with observations from local weather radars (C- and/or X-band) and local meteorological stations to produce a higher-resolution (500×500 m², 5 min) grid with focus on rainfall for urban needs. The local/urban data will furthermore be used for short-term rainfall nowcasting. Different approaches to quality control are being developed, implemented and evaluated, including code developed within OpenSense.

Both the national and local/urban products are intended for hydrological applications. On the national scale, the data will be used as forcing (spin-up) data in the national flood forecasting model S-HYPE, with a 1-h time step. On the local/urban scale, the data will be used for urban hydrological applications including real-time control of sewer systems as well as of facilities for rainwater harvesting. Experiments are being conducted and conceivably operational production will begin in 2026.

OpenSense has been important for the above development at SMHI, both owing to a number of STSMs and other grants, and more generally from the opportunity to network and discuss with colleagues at various meetings.

3.2. MEMO at SMHI

At SMHI a demo was developed to show the feasibility of having near-realtime processing of CML data to precipitation maps (https://www.smhi.se/MEMO). The demo was developed for the two major cities in Sweden: Stockholm and Gothenburg. Every 10 seconds data were collected and processed in one-minute batches. Processing to rainfall maps can be done under a minute with a near real-time delay of <2 mins. Due to the end of the project only demo data are now available. Merging of CML data with radar data was also tested, but is not included in the demo site. Similar to France, continuation of CML usage is dependent on the result of ongoing cost benefit considerations.

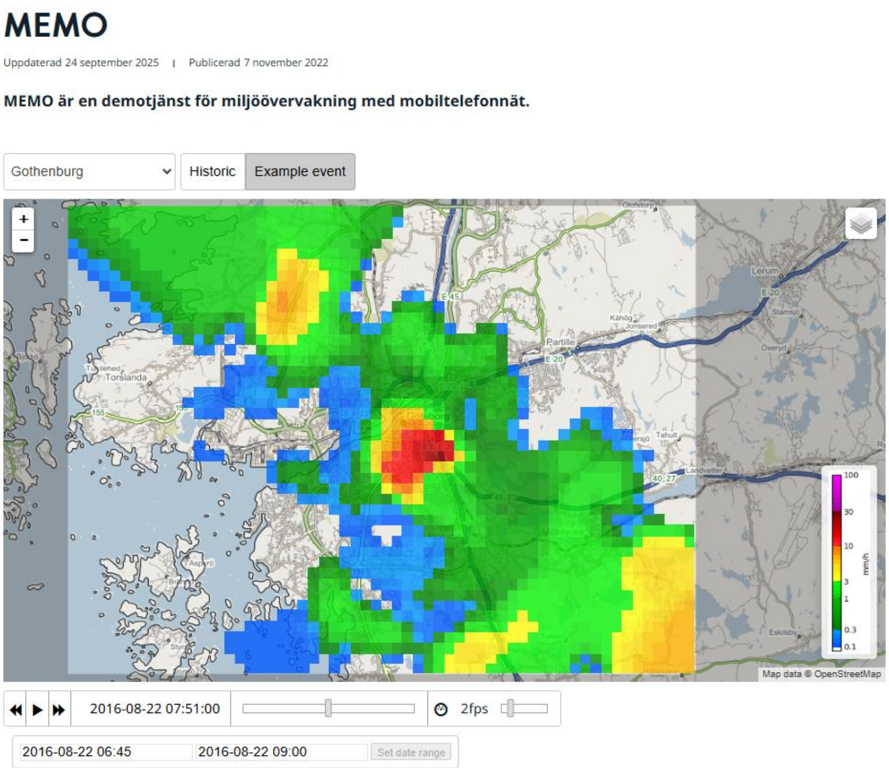

Fig 2. An example from the MEMO demo website of precipitation in Gothenburg, Sweden.

4. Case study in France - Raincell project

After a proof of concept study, in 2022 Météo-France started a project named Raincell with two partners, in order to use commercial microwave links (CMLs) data to improve quantitative precipitation estimation (QPE), in addition to standard sensors as rain gauges and weather radars (Faure et al. 2024). The scientific partner is IRD (Institut de Recherche pour le Développement) which has a long experience on CML data use, and the CML data provider is the telecommunication operator Orange.

From December 2022 to June 2024, Orange collected and transmitted in real time to Météo-France high resolution CML data (15 seconds, 0.1 dB of digitalisation, 2 channels by link), covering mainland France and some overseas territories. Simultaneously, two different kinds of software was developed at Météo-France to produce rainfall estimates from the signal attenuation of the CMLs: a classic software based on the scientific literature on this topic (baseline definition, wet-dry periods identification, wet antenna attenuation correction, rainfall estimation), and a machine learning (ML) approach, based on deep learning, used both for wet-dry periods segmentation and rainfall estimation. This first phase of the project was completed in mid-2024, and is described in Faure et al. 2024.

A second phase (mid-2024 – mid-2025) permitted testing different approaches to take into account the CML estimates (classic and ML) into the best QPE product delivered by Météo-France named Antilope. Validation results showed a general improvement of Antilope by comparison with rain gauges measurement used as a reference. But this improvement is limited for now, which does not produce an interesting cost-benefit ratio, which must take into account the cost of implementing an operational application involving Météo-France and Orange, the cost of maintenance in operational condition of this system, and the price of a data subscription with Orange. The final decision has not been made yet.

5. Eumetnet IoT expert team

Eumetnet started exploring PWS at the same time as OpenSense (Hahn et al. 2022) and set up an expert team on IoT in 2023 that included members of OpenSense. The main goals of the ongoing activity is to accelerate the uptake of opportunistic, or as called within that initiative IoT, sensors at national meteorologic and hydrometeorologic services. The expert team does not focus solely on precipitation and explores the usage of other PWS variables as well as other sensors like smartphone pressure data or camera footage. A big success so far is a collaboration with Netatmo that should start a real time data stream of PWS data to all Eumetnet members in the second half of 2025.

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