Brussels, 25 May 2021

COST 076/21

DECISION

Subject: Memorandum of Understanding for the implementation of the COST Action “Opportunistic precipitation sensing network” (OPENSENSE) CA20136

The COST Member Countries will find attached the Memorandum of Understanding for the COST Action Opportunistic precipitation sensing network approved by the Committee of Senior Officials through written procedure on 25 May 2021.

Funded by the Horizon 2020 Framework Programme of the European Union

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA20136
OPPORTUNISTIC PRECIPITATION SENSING NETWORK (OPENSENSE)

The COST Members through the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action, referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any document amending or replacing them.

The main aim and objective of the Action is to improve access to continental opportunistic sensing (OS) observations, establish OS as a widely acknowledged method capable of providing reliable operational precipitation observations, and facilitate their use in precipitation nowcasting and operational hydrological forecasts. This will be achieved through the specific objectives detailed in the Technical Annex.

The present MoU enters into force on the date of the approval of the COST Action by the CSO.

OVERVIEW

Summary

Despite advances in remote sensing, precipitation observations remain one of the weakest links in the description of Earth's water cycle. This is especially critical in the face of climate change, human-induced hydrologic changes e.g. due to rapid urbanisation, and consequent increase in frequency and magnitude of extreme events. Opportunistic sensing can greatly improve spatial and temporal resolution of standard precipitation monitoring networks on continental scale by complementing them with measurements from personal weather stations or devices primarily not intended for precipitation monitoring such as commercial microwave links or broadband satellite terminals. The number of opportunistic sensors has already now exceeded traditional in-situ observations by an order of magnitude, and it is increasing exponentially. Nevertheless, it is still unclear how to make this data operationally accessible, achieve robust quality control of these observations, and integrate them into standard observation systems.

OPENSENSE brings together scientists investigating different opportunistic sensors, experts from national weather services, owners of sensor networks, and end-users of rainfall products to build a worldwide reference opportunistic sensing community. It will i) overcome key barriers preventing data exchange and acceptance as hydrometeorological observations ii) define standards to allow for large-scale benchmarking of OS precipitation products developing new methods for precipitation retrieval iii) coordinate integration of the opportunistic observations into traditional monitoring networks, and iv) identify potential new sources of precipitation observations.

These coordinated activities will boost uptake of OS as precipitation observation methods and enable generation of high-quality precipitation products with unprecedented spatial and temporal resolution.

Areas of Expertise Relevant for the Action	**Keywords**
● Earth and related Environmental sciences: Hydrology, water resources ● Electrical engineering, electronic engineering, Information engineering: Signal processing, 1-D and multidimensional signal processing, compression, signal acquisition ● Environmental engineering: Databases, data mining, data curation, computational modelling	● climate change ● hydrometeorological observations ● rainfall retrieval ● interoperable sensor data ● data mining and value creation

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

<u>Research Coordination</u>

● RCO1 Define common data formats and metadata requirements for different types of opportunistic sensors.
● RCO2 Coordinate OS data curation at the international level combining different types of OS from different regions and establish open access to this database.
● RCO3 Establish a database of benchmark datasets for standardized testing of new algorithms for quality control of OS and their assimilation with traditional observations.
● RCO4 Coordinate a benchmarking of algorithms for fast processing and quality control of OS observations suitable for operational use.
● RCO5 Coordinate joint research agenda on methods for OS processing, quality control, and uncertainty

assessment and synchronize community development of software implementing these methods.

● RCO6 Establish operational access to OS precipitation products at least in two regions to facilitate their use (and indirect verification) in precipitation and hydrological forecasts.

● RCO7 Disseminate results on OS research to relevant stakeholders and create awareness about challenges and opportunities related to OS precipitation retrieval and application.

● RCO8 Support application of OS observations and precipitation products in operational precipitation nowcasts and hydrological forecasts.

● RCO9 Identify strategies for unlocking OS data and global upscaling of OS weather monitoring.

Capacity Building

● CBO1 Consolidate the existing collaborations and foster knowledge exchange and joint research agenda on OS.

● CBO2 Connect hydrologists, meteorologists, climatologists, statisticians, and electrical and signal processing engineers and software developers to combine knowledge on the atmosphere, hydrometeorological observations and advanced signal processing methods to become worldwide reference community on the subject.

● CBO3 Establish the link between OS research, national meteorological services, OS data providers and precipitation product end-users; and act as a platform for coordinating integration of OS precipitation observations into standard observation networks and for communicating and removing barriers that prevent sharing of new sources of OS data.

● CBO4 Involve Early Career Investigators (ECI) into management of the Action and leading of Working Groups and increase their visibility and inclusion into OS community.

● CBO5 Provide training for ECI on processing and usage of OS data and on experimentation with new OS techniques emerging with technological development.

● CBO6 Foster collaboration and exchange of PhD students by organizing STSMs (Short-Term Scientific Missions).

● CBO7 Integrate researchers from COST Inclusiveness Target Countries as well as from Near Neighbour Countries into the community and mitigate their handicap given by economic conditions.

● CBO8 Promote open science policies and train Action participants in using tools provided by the European Open Science Cloud.

TECHNICAL ANNEX

1. S&T EXCELLENCE

1.1 SOUNDNESS OF THE CHALLENGE

1.1.1 DESCRIPTION OF THE STATE-OF-THE-ART

Accurate and timely surface measurements of precipitation are of paramount importance for e.g. weather prediction, climate research, agriculture, or effective water resources management, as well as ground calibration and validation of satellite-based precipitation estimates (Kidd and Huffman, 2011). Operational precipitation observations are needed also in variety of fields not directly related to water cycle, e.g. for management of road traffic, optimisation of wind turbine performance, or mitigation of propagation impairment of advanced satellite communication systems.

However, the majority of the Earth's land surface lacks data of sufficient quality about rainfall intensity. In many regions, data becomes available only after a delay of several years (Becker et al., 2013) and at coarse temporal resolution (e.g. daily averages). Additionally, in many parts of the world the data availability of surface precipitation gauging networks is declining (Lorenz and Kunstmann, 2012). Although satellite precipitation missions provide global precipitation products, these measurements are still inaccurate and do not have the sufficient temporal and spatial resolution to drive local hydrological models e.g. of cities or small mountain catchments (Kidd and Huffman, 2011). Weather radar observations are mostly limited to developed countries (Heistermann et al., 2013), however, even in these regions there are observational gaps, specifically in mountainous and urban areas, where radar observations are disturbed (Berne and Krajewski, 2013) and rain gauge densities are low.

Fortunately, the rapid growth of cellular and Wi-Fi networks together with the rise of "smart connected devices" (internet of things, IoT), dramatically increases the number of potential precipitation sensors. The global number of connected devices has recently been estimated as approx. 17 billion and the number is increasing exponentially (Ericsson, 2019). An inexpensive and open source hard- and software (e.g. Arduino) has facilitated the use of low-cost sensors in many different fields (Swan, 2012). Use and development of low-cost purpose-made sensors is also becoming more frequent among experimental hydrologists (Tauro et al., 2018). Open and collaborative platforms provide instructions and training for building own purpose-made sensors (e.g. OPEnS Lab) and facilitate data sharing (e.g. Crowd Hydrology or Weather Underground) and "citizen science", in general. For example, crowd-sourced temperature observations from Netatmo personal weather stations have recently enabled great improvement in short-term weather forecasts for Nordic countries (Nipen et al., 2019) and crowd-sourced precipitation observations might have similar potential. The Weather Underground platform gathers observations from more than 250,000 weather stations including both professional but mainly personal ones. Such observations could greatly improve density of in-situ precipitation observation networks (Vos et al., 2019). Note that a similar number of official rain gauges exist, but only a fraction of that number provide useful observations (Strangeways, 2006). Unfortunately, voluntary reported precipitation observations are almost exclusively limited to developed regions, and thus cannot efficiently complete often scarce weather monitoring networks in developing countries.

The opportunistic sensing (OS) of precipitation is, however, not limited to crowdsourcing, but can also benefit from other devices, which either directly observe weather conditions (e.g. sensors in building automation), or are distorted by them (commercial microwave links), as these devices are also increasingly becoming available online. Commercial microwave links (CMLs) represent a prominent example of unintentional precipitation OS with great continental coverage, in total about 5 million CMLs are deployed globally (Ericsson, 2019). CMLs are point-point radio connections used as the backbone of cellular networks. CMLs operate on frequencies where raindrops substantially attenuate radio signal.

This attenuation is almost linearly related to the rainfall intensity along the CML path, which makes CMLs potentially highly accurate rainfall sensors (Chwala and Kunstmann, 2019). Moreover, CML data are accessible online in (near) real-time from network operation centres either through network monitoring systems or through specifically designed server sided applications (Chwala et al., 2016). Tens of studies have already demonstrated the potential of CMLs for different hydrometeorological applications in the recent decade (Chwala and Kunstmann, 2019) including for example, reconstruction of countrywide rainfall maps (Graf et al., 2019), use of CMLs for sparsely gauged regions (Doumounia et al., 2014), or joint use of CMLs, rain gauges and weather radar to improve short-term (sub-hourly) rainfall forecast (Bianchi et al., 2013), or recently CML based nowcasting (Imhoff et al., 2020).

Another promising OS rainfall retrieval method utilises data about signal loss between geostationary satellites for digital video broadcasting (DVB) (Barthès and Mallet, 2013) or broadband services (Giannetti et al., 2019) and ground terminals, which are integral part of commercial-grade equipment for direct-to-home TV. There is a high number of terminals already installed for direct-to-home (DTH) satellite TV reception, each of which could, in principle, constitute a device for the opportunistic measurement of precipitations. For instance, Eutelsat, which is Europe's most long-standing satellite operator and the third largest globally (EUT01), delivers its TV channels to 135 million of homes in Europe (EUT02) and this makes this method highly promising for operational use in the near future (Giannetti et al., 2019). Furthermore, satellite-based OS can reveal very effective especially if used in conjunction with CMLs, because even a limited number of low-cost commercial-grade satellite receive terminals, either already in-place for DTH or purposely installed, can cheaply fill the gaps of the CML meshed network on the ground. Additionally, the measurements along the slanted paths of the satellite links can add a vertical dimension to conventional 2D CML-based algorithms, enabling thus a 3D reconstruction of the precipitation.

Intentional opportunistic sensors, such as personal weather stations, are often low-cost devices. However, these are mostly not calibrated, and often not properly installed and regularly maintained. Unintentional opportunistic sensors are, on the other hand, often high-tech and well-maintained devices. But they are optimised and controlled for their primary function (e.g. telecommunication by CMLs), not for precipitation observations. Quality control methods such as range/limits, time and internal consistency or persistence and spatial consistency tests (Estévez et al., 2011) routinely applied to traditional precipitation ground observations have proven to be essential to exploit full potential of these observations for hydrological and meteorological applications. OS devices have, however, diverse characteristics and are operated and maintained by different stakeholders. Securing access to OS observations, gaining an acceptable quality and reliable assessment of their errors is, therefore, highly challenging and requires involvement of different stakeholders and development of a completely new methodological framework.

OPENSENSE focuses on three very promising opportunistic precipitation sensing systems using sensors with worldwide coverage: Broadband/broadcast satellite terminals, situated between Technology Readiness Levels (TRL) 5 & 6, CMLs, situated between TRL 6 & 7, and personal weather stations (TRL 7 & 8). In addition, OPENSENSE gives attention to emerging technologies, which will open new opportunities for both intentional and unintentional weather monitoring. For example, 5G cellular communication will employ micro-cells, for which more backhaul CMLs are required, nevertheless they will operate at higher frequency bands which are more sensitive to rainfall, but also to other agents, e.g., water vapor (Fencl et al., 2020). Moreover, 5G will also use microwave frequencies in the fronthaul, i.e., the connection between cell phone towers and mobile devices, where it cannot be replaced by fiber technology. The leading opportunities for OS sensing are also in phase measurements, associated with MIMO technology, and in polarisation.

Definitely, the number of OS is now already exceeding the number of traditional in-situ observations and it is likely to be of orders of magnitude higher in the near future, which makes OS a very promising precipitation observation method.

1.1.1. DESCRIPTION OF THE CHALLENGE (MAIN AIM)

With advancement of computational power, numerical modelling and satellite-based remote sensing of Earth's surface, precipitation observations remain one of the weakest links in the description and understanding of Earth's water cycle at different spatial and temporal scales. This is especially critical in the face of climate change, human-induced hydrologic changes e.g. due to rapid urbanisation, and consequent increase in frequency and magnitude of extreme events. For example, the extreme heavy rainfalls (cloudbursts), which hit Copenhagen several times in the recent decade (2010, 2011 and subsequent years) and caused severe pluvial flooding, or the extreme rainfall connected to Vb-cyclones in the Balkans in 2014 (Stadtherr et al., 2016) causing severe fluvial flooding will unfortunately occur more often at a majority of EU regions due to ongoing climatic change(Deutsche Akademie der Naturforscher Leopoldina, 2013). Precipitation observations at high spatial and temporal resolution are crucial to predict occurrence, evolution, and effects of extreme events such as fluvial/pluvial flooding. The existing available rainfall observations from weather radar and rain gauge networks are, however, not always sufficient, in particular in urban and mountainous areas. In less developed regions weather radars are often not available at all and gauge networks are sparse.

OPENSENSE aims to improve access to continental OS observations, establish OS as a widely acknowledged method capable of providing reliable operational precipitation observations, and facilitate their use in precipitation nowcasting and operational hydrological forecasts. The challenges addressed by OPENSENSE include research questions related to the following aspects of opportunistic sensing:

a. <u>Reliability of opportunistic sensors and OS processing methods:</u> How to evaluate the reliability of opportunistic sensors and evaluate performance of new processing algorithms in a scientifically rigorous way? What are the minimal and optimal quality of data and metadata for different services required to accept opportunistic precipitation sensor measurements as informative precipitation observations?
b. <u>Operationalisation of precipitation products:</u> How to process large volumes of OS data in (near)-real time to facilitate their use in operational forecasting? How to automate quality control and uncertainty assessment of OS precipitation observations in operational mode? How to ensure interoperability of OS processing algorithms?
c. <u>Merging techniques and application:</u> How to efficiently merge OS precipitation observations with observations from traditional monitoring networks? How to deal with variable density and quality of OS sensors? How to improve precipitation and hydrological forecasting using OS?
d. <u>OS upscaling:</u> How to facilitate transboundary exchange of OS data? How to upscale OS precipitation monitoring from local and regional scale to the global scale? Which emerging technologies have the potential to become opportunistic sensors providing reliable precipitation and other weather observations?

OPENSENSE will establish interdisciplinary and transboundary collaboration between researchers and stakeholders from different sectors, which is required to address these questions.

In summary, in many parts of the world the data availability of surface precipitation gauging networks is declining. In contrast, the number of opportunistic sensors has already now exceeded the number of traditional in-situ observations by an order of magnitude. Moreover, this data is often available in real time. Nevertheless, it is still unclear how to rigorously evaluate the quality of these observations, routinely integrate them into standard observation systems, and efficiently use them to improve weather and hydrological forecasting. The challenges related to OS are relevant and timely, because now, companies are starting to harvest opportunities, to fully exploit the potential of this rapidly evolving field. Collaboration among scientists across Europe (and beyond) is needed to disseminate research advancements, develop common standards and boost innovation by including multi-stakeholder from the private sector, policymakers as well as the civil society.

1.2 PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1 APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE-OF-THE-ART

The OPENSENSE network advances the OS field beyond the state of the art in four areas: i) standardisation and benchmarking, ii) operationalisation (preparing tools for processing OS data in real-time), iii) indirect validation of OS through different applications, iv) Overcoming key barriers preventing upscaling OS observations to European and/or global scale and identification of emerging technologies with potential for OS sensing. Approach and expected progress are listed in the table below:

Table 1: Approach to the challenge and progress beyond the state-of-the-art

	Approach to the challenge	**Progress beyond the state-of-the-art**
Standardisation	Coordinating the compilation and publishing of benchmark datasets covering i) representative samples of sensors ii) different climatological regions iii) and sufficiently long period of OS records.	Scientifically rigorous assessment of OS methods, which have been up until now mostly proposed and evaluated within separate case studies often under sensor-, site-, and climate-specific conditions.
	Defining common data formats and standards on metadata (minimal and optimal) for different types of sensors.	Interoperability of software tools and automated processing routines applicable for different datasets.
Operationalisation	Knowledge exchange between experts in signal processing, wireless communication, and hydrology and meteorology. Sharing and harmonizing software tools for fast processing and quality control of OS observations. Combining data-driven and physically based approaches.	Upgraded algorithms for controlling quality and assessing uncertainty of OS observations capable of processing large volumes of data in operational settings.
	Joint curation of datasets from different Action Members - establishing and updating database with multi-sensor OS datasets geographically covering several neighbouring countries.	OS precipitation observations with unprecedented geographical coverage and space-time resolution openly available for testing and application.
Application	Establishing strong links between development of OS methods and application of precipitation products (e.g. by meteo services). Establishing operational access to OS data to facilitate their use in nowcasting and hydrological modelling.	Extensive (continuous) validation of OS observations through application. Methods for integrating OS to short-term precipitation and hydrological forecasts. Improved precipitation and hydrological forecasts in sparsely gauged regions.
	Coordinate research on merging of standard and OS observations.	Precipitation products with unprecedented spatial and temporal resolution.
Upscaling	Bringing together scientists and stakeholders from hydrology, meteorology, wireless communication and other relevant fields. Identification of key legal, economical, organisational, technical and scientific challenges with regard to global upscaling of OS systems.	Realistic strategies for global upscaling of OS methods, which have up until now been developed and operated at local or national scale. Identification of emerging technologies with potential for new intentional and unintentional OS.

1.2.2 OBJECTIVES

1.2.2.1 Research Coordination Objectives

The objectives are specific in addressing challenges identified as being timely and relevant (1.1.2) and will thus enable progress in the field of OS beyond the state-of-the-art (1.2.1). They are achievable and time-related as they are clearly linked to activities and tasks of working groups and their timeframe (4.1.1,2,4) and their success can be measured through concrete and visible deliverables.

RCO1: Define common data formats and metadata requirements for different types of opportunistic sensors.
RCO2: Coordinate OS data curation at the international level combining different types of OS from different regions and establish open access to this database.
RCO3: Establish a database of benchmark datasets for standardised testing of new algorithms for quality control of OS and their assimilation with traditional observations.
RCO4: Coordinate a benchmarking of algorithms for fast processing and quality control of OS observations suitable for operational use.
RCO5: Coordinate joint research agenda on methods for OS processing, quality control, and uncertainty assessment and synchronise community development of software implementing these methods.
RCO6: Establish operational access to OS precipitation products at least in two regions to facilitate their use (and indirect verification) in precipitation and hydrological forecasts.
RCO7: Disseminate results on OS research to relevant stakeholders and create awareness about challenges and opportunities related to OS precipitation retrieval and application.
RCO8: Support application of OS observations and precipitation products in operational precipitation nowcasts and hydrological forecasts.
RCO9: Identify strategies for unlocking OS data and global upscaling of OS weather monitoring.

1.2.2.2 Capacity-building Objectives

CBO1: Consolidate the existing collaborations and foster knowledge exchange and joint research agenda on OS
CBO2: Connect hydrologists, meteorologists, climatologists, statisticians, and electrical and signal processing engineers and software developers to combine knowledge on the atmosphere, hydrometeorological observations and advanced signal processing methods to become worldwide reference community on the subject
CBO3: Establish the link between OS research, national meteorological services, and other stakeholders (OS data providers and precipitation product end-users) and act as a platform for coordinating integration of OS precipitation observations into standard observation networks and for communicating and removing barriers that prevent sharing of new sources of OS data
CBO4: Involve Early Career Investigators (ECI) into management of the Action and leading of Working Groups and increase their visibility and inclusion into OS community
CBO5: Provide training for ECI on processing and usage of OS data and on experimentation with new OS techniques emerging with technological development
CBO6: Foster collaboration and exchange of PhD students by organising STSMs (Short-Term Scientific Missions)
CBO7: Integrate researchers from COST Inclusiveness Target Countries as well as from Near Neighbour Countries into the community
CBO8: Promote open science policies and train Action participants in using tools provided by the European Open Science Cloud.

2. NETWORKING EXCELLENCE

2.1. ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1. ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

OPENSENSE is a unique effort to synchronise the work of researchers and stakeholders from the field of opportunistic sensing of precipitation. Several individual research projects have laid the scientific foundations in this field, but, up to now, no effort has been undertaken to connect and harmonise these individual developments. OS of precipitation is now at a stage where a research community has to be formed around standardised benchmark datasets and with standardised interfaces for data and knowledge exchange to be able to progress. Furthermore, the challenge of OS data access and sharing is similar for all active research groups and should be tackled jointly. Heavy precipitation events and associated flooding are often transboundary events and so must be the initiatives to cope with them.

OPENSENSE will go beyond former and existing research projects by:

- tightly connecting the precipitation OS research groups to collect and standardise the knowledge and methods derived in the individual past research projects
- defining data exchange formats (including standardizing metadata) and interfaces to foster interdisciplinary and transboundary exchange of precipitation OS data
- jointly defining benchmark methods and collecting benchmark datasets
- demonstrating potential of OS data in both local and transboundary real-world applications
- connecting researchers and stakeholders to identify sustainable strategies (business models) for unlocking current and future OS observations and utilizing them in real-world applications.

OPENSENSE will coordinate its efforts to be compatible with GEOSS and Copernicus observation platforms. It will collaborate with the EUMETNET network, which gathers 31 European national meteorological and hydrological services. Specifically, OPENSENSE will coordinate its activities with the OPERA programme for operational exchange of weather radar information and the evolution of the EUMET composite observing system (EUCOS). OPENSENSE will also cooperate with the ESA CERASAT project for centralised rainfall estimation using data from the network of broadband satellite terminals. With respect to citizen science and crowdsourced observations OPENSENSE will collaborate with H2020 research projects WeObserve (2018-2022) which aims at creating sustainable ecosystems for Citizen Environmental observations, and TWIGA (2018 - 2022) which aims at enhancing satellite based geo-information on weather, water and climate for sub-Saharan Africa by innovative in-situ sensors operated by local citizens. OPENSENSE will also collaborate with research and application projects which use precipitation as a key input, specifically with DAMOCLES (2018-2022) which investigates processes and variables underpinning compound events. Moreover, it will profit from the experiences gathered in IMDROFLOOD (2016-2020) which combines available hydrological, meteorological observations, and remote sensing data to improve flood and drought risk management. OPENSENSE also connects to ongoing European national projects, as well as the ongoing OS projects in developing countries including Nigeria, Papua New Guinea, or Sri Lanka.

OPENSENSE will coordinate and communicate its activities with the MOXII working group under the International Association of Hydrological Sciences, which promotes advancement of novel observation techniques, and with subdivisions on Precipitation & climate and on Catchment hydrology under the European Geoscience Union. It will also collaborate with the IWA/IAHR International Working Group on Urban Rainfall, which focuses on rainfall monitoring at detailed spatial and temporal scales required for urban water management. Finally, it will coordinate its efforts with the International Precipitation Working Group (IPWG), which is a permanent Working Group of the Coordination Group for Meteorological Satellites and is co-sponsored by the World Meteorological Organization (WMO). IPWG recently officially acknowledged CMLs as a valuable precipitation source and is interested in applying CMLs to validate satellite precipitation products.

2.2. ADDED VALUE OF NETWORKING IN IMPACT

2.2.1. SECURING THE CRITICAL MASS AND EXPERTISE

Creating value from opportunistic sensing, especially the unintentional OS, is complex because it requires a broad range of stakeholders and technologies from different sectors. Interdisciplinary expertise from remote sensing to hydrology and socioeconomics is, therefore, required to address efficiently the challenges related to OS. Current efforts are mostly limited to demonstration of OS capabilities at local or national scale and broader international collaboration is limited to knowledge exchange on scientific conferences.

OPENSENSE will gather a critical mass of expertise by involving participants from the required fields, such as water management, hydrology and hydrological monitoring, meteorology, signal processing, electrical engineering, wireless communication and socioeconomics. Key experts involved in research and development of new OS methods as well as experts having experience in applying these data in precipitation and hydrological forecasting, are involved in the Network of Proposers. Their geographical distribution is favourable as it covers COST Member Countries (and Palestine as a Near-Neighbour country) with frontier, emerging and developed markets. The distribution therefore strongly reflects substantial socioeconomic differences influencing OS in terms of territory coverage, willingness/capability to maintain OS and share their data, but also reflects traditional precipitation observation networks in terms of density and quality. The geographical distribution of the Network is also representative in terms of climate classification. Hence, the COST Member Countries reflect a broad variety of requirements for precipitation monitoring in different regions.

The expertise and geographical distribution of the initial consortium has the critical mass to address the Action challenges and objectives. The wide range of expertise contained in the initial consortium will facilitate involvement of relevant researchers and stakeholders during the Action and enable the building of a worldwide reference community in the field of OS. The working group dedicated to Stakeholder involvement (WG4) will foster active involvement of the most relevant players into the Action.

The access to OS observations, which is crucial for reaching the Action's objectives, is already secured through the Network of Proposers which involves several participants who have access to this data on a national level. The Action, however, aims to sustain its impact and upscale the OS to global level. The Network of Proposers, therefore, involves GSMA, which is the association which unites more than 750 mobile operators worldwide, within 350 companies in the broader mobile ecosystem including software and hardware providers, internet providers, etc., i.e. major owners and developers of CML infrastructure. The involvement of national weather services, on the other side, secures harmonisation of opportunistic precipitation observations with traditional ones and connects to areas of applications like operational severe weather warnings and climate monitoring. Moreover, the involvement of SME consultants from the field of water management creates important links to OS data end-users. Finally, development of common OS data/metadata standards will facilitate closer collaboration between Action participants and create the momentum needed for upscaling the OS from local to European and global scale.

2.2.2. INVOLVEMENT OF STAKEHOLDERS

OPENSENSE will maximise its impact by involving the most important stakeholders with different roles, including not only researchers, but also data owners/providers, data curators/managers (e.g. national weather services) and precipitation product end-users. The researchers and stakeholders will be from different fields/sectors, e.g. hydrology, signal processing, electrical engineering, and telecommunication. One whole working group is dedicated to communication between different stakeholders, analysing their needs and identifying constraints limiting their willingness to i) share OS data and ii) merge them with standard observations, and iii) use them as end-users. The participation of one of the trade associations gathering mobile network operators is key to involve mobile network operators and technological leaders in the wireless communication into the Action. To ensure the tight integration across the different knowledge domains, one working group specifically addresses stakeholder engagement (see tasks of WG4 in 4.1.1).

The Action will facilitate communication between data owners, curators and precipitation data end-users by inviting them to participate in Working Group meetings and Workshops, and other cross-cutting events and by organizing round tables on specific issues (business models for monetizing OS data, quality requirements on OS data, or technical aspects of their acquisition). The involvement of researchers will be, in addition to invitations to general meetings and Training Schools, facilitated by an active promotion of the Action within the expert working groups mentioned in section 2.1.1 and at scientific conferences e.g. by (co-)organising special sessions on OS at important conferences such as the European Geoscience Union General Assembly.

The Action will actively collaborate on integrating OS in standard monitoring networks with official maintainers/curators of national and regional precipitation observation networks (several are involved already in the network of proposers). The Action Management Committee will also facilitate "unlocking" of OS precipitation (and other weather) data by supporting OS research & innovation projects at national levels, e.g. through letters of support referring to examples of good practice.

2.2.3. MUTUAL BENEFITS OF THE INVOLVEMENT OF SECONDARY PROPOSERS FROM NEAR NEIGHBOUR OR INTERNATIONAL PARTNER COUNTRIES OR INTERNATIONAL ORGANISATIONS

In this Action, great mutual benefit occurs from involving GSMA and An-Najah National University.

The GSMA, a professional association uniting cellular operators worldwide, will facilitate communication between mobile network operators and meteorologists and hydrologists. Specifically, GSMA will support efforts of Action members to 'unlock' data from unintentional OS related to the operation of wireless networks (e.g. CML data, or 5G). It will be closely involved in marking up strategies for 'unlocking' the OS data at global scale. The GSMA will benefit from the opportunity to influence future research on OS, from gaining knowledge on OS potential (which might be monetised in the future by mobile network operators or used for mobile network development). The national meteorological services, precipitation data end-users and researchers will benefit from GSMA involvement in data unlocking and from GSMA knowledge on potential and evolution of recent and emerging technologies (microwave link backhaul, 5G, LoRa, etc.) as well as developing business models.

The partner from An-Najah National University (Nablus, Palestine) represents a stakeholder from a developing country where OS has the potential to substantially improve space-time resolution of standard precipitation observations, which are currently sparse. The partner will benefit from knowledge transfer. The Action will benefit through gaining experience on OS use in a country with a frontier market and through access to the OS data. An-Najah National University has already started to analyse CML data in the region of Nablus and sees great benefit in using OS data to improve rainfall observations in the data scarce region of the West Bank.

3. IMPACT

3.1. IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1. SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

OPENSENSE will define a methodological framework for rigorous testing of new OS processing algorithms which will improve uptake of this new source of information. Furthermore, methods developed within OPENSENSE will improve the readiness of OS to be applied to real-world problems. For example, the improvement of CML processing algorithms together with automated quality control will progress CML rainfall retrieval technology within the duration of the Action from the technology readiness level corresponding to Technology Development (TRL 6-7) to the level corresponding to Technology Demonstration (TRL 8). Similarly, the improvement of processing algorithms for rainfall retrieval from broadband/broadcast satellite terminals will progress such a technology from TRL 5-6 to TRL 7. OPENSENSE will also establish communication between sensor operators, weather observation curators and precipitation data end-users which will lead to more active involvement of the stakeholders (especially national hydro-meteo offices) in OS data retrieval and use. Improved access to OS data together with automation and improvement of recent quality control and uncertainty assessment techniques will boost use of OS for precipitation nowcasts and hydrological forecasts. This will reduce damage to property and infrastructure related to precipitation driven events, such as pluvial/fluvial flooding, and prevent loss of life. In the long term, the integration of a larger number of OS into precipitation (and other weather) monitoring systems will improve description, understanding and modelling of water cycle.

OPENSENSE has the critical mass to build a globally recognised OS community, which will survive the end of the Action and facilitate future advancement of the OS field. Pathways for applying OS observations in weather and hydrological forecasts will in the short term open new business opportunities for owners of wireless infrastructure or new opportunities (esp. for corporations) to show societal responsibility. The personal weather stations (TRL 8) are already monetised. However, quality control measures improved and automated within OPENSENSE will, in the short term, open opportunities for new applications and pathways for improvement of their hardware. Active involvement of national hydro-meteo offices into the network is crucial for sustainability of both the network and access to OS precipitation products. The Action will also strengthen link between academia, meteo offices, and stakeholders producing OS data and will search for means (business models, memorandums of cooperation, etc.) for formalizing these connections.

Finally, identification of emerging technologies with potential for precipitation sensing and for (un)intentional observations of other weather variables will show direction for future high-impact research in the field of OS weather monitoring.

3.2 MEASURES TO MAXIMISE IMPACT

3.1.2. KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

OPENSENSE will create knowledge mainly through active collaboration of Action members on tasks addressing the Action's objectives and through COST networking tools. Open collaborative platforms with github and gitlab-page features and shared data repository will be established at the onset of the Action (activities of WG1,2 and 5, in section 4.1.1), which will facilitate involvement of broader scientific community into Action's activities, stimulate knowledge-exchange, and ease coordination of joint research agenda. OPENSENSE involves key experts from different fields including meteorology, hydrology and hydrological modelling, electrical engineering, signal processing, wireless communication, data management, and socioeconomics. The Action Management Committee will ensure that all Working Groups will be highly interdisciplinary to efficiently tackle the challenges.

OPENSENSE will maximise its impact by involving stakeholders from different sectors including National Weather Services, wireless communication providers, policy makers, humanitarian and developmental organisations, engineering companies and water management companies, i.e. actors involved in intentional and unintentional precipitation monitoring and, on the other side, actors often challenged by the lack of precipitation observations of sufficient spatial and temporal resolution. One Working Group (WG4) is dedicated to communication between stakeholders and researchers. WG4 will survey stakeholder needs, organise regular online stakeholder round-table discussions, and invite them to events focused on cross-cutting issues. The transfer of knowledge between broader scientific communities will be ensured through standard channels such as international conferences. The transfer of knowledge between OPENSENSE and mobile network operators is ensured through the involvement of one of the wireless communication trade unions already in the Network of Proposers. OPENSENSE meetings will generally be open and will be broadcasted online to reach relevant researchers worldwide with an interest in the Action scope. The Action meetings will be advertised through the Action website, by standard communication tools within the scientific community (expert lists) and through individual professional networks of Action participants. The collaborative results of the activities will be promoted at international conferences and meetings. Two Training Schools will be organised, one more research-oriented and the other application-oriented targeting OS stakeholders in operational hydrology and water management.

The Action will support the career development of young talents using several tools. ECI and PhD students will be in close contact with the leading experts, which will provide them the visibility within the community. They will collaborate on individual research tasks and will be supported by STSM (4-6 per year) to increase their skills and international relevance. Furthermore, ECI and PhD students from ITC will be supported by ITC conference grants to actively participate in international conferences. OPENSENSE will organise two Training Schools focusing on the transfer of the knowledge in which ECIs will be involved both as trainees and trainers. Finally, ECI will take the leading managing role in workshops and Action Meetings and will be also involved as leaders of Work Groups (at least two positions of working group leader will be reserved to ECI). The active participation in organisation of OPENSENSE's activities will foster competences of young researchers needed for taking leading roles in their future careers.

The gender balance in the technical sciences is historically biased towards males, especially in the ITC countries, and this imbalance is especially pronounced at leading positions. OPENSENSE will, therefore, focus on the measures to ensure the participation of highly qualified women as leaders of Working Groups and as speakers at workshops or Training schools, counteracting sociocultural barriers limiting women scientific careers. A significant number of women within the network of proposers provides a solid basis to reach these objectives.

To stimulate the participation in Action activities and to increase the scientific relevance of ITC researchers, OPENSENSE will invite ITC participants to leading positions.

3.2.2 PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

OPENSENSE will disseminate results using different communication strategies to target i) researchers, ii) consultants and industry, iii) decision and policy makers in water management, and iv) the general public. The impact of Action's events (Meetings/Workshops/Training Schools) will be strengthened by recording and streaming them (e.g. through a dedicated YouTube channel). In addition, online conference tools (MSTeams, Zoom, or dedicated meeting platforms) will be used to motivate the observers of from the broader research community, and experts from industry, consultancy and public sectors, to participate actively on Action activities. Work presented on Workshops will be published as conference proceedings and/or special issues. A scientific audience will be targeted although through journal papers and contributions at conferences and topical workshops. The visibility of publications will be increased by advertising them on the Action website and the Action social media accounts. To target consultants, industry, and policy makers, the application results will be (at least two times) published in magazines for water professionals such as The Source (monthly published by International Water Association) or NewsFlash Europe (monthly published by International Association for Hydro-Environment Engineering and Research). The dissemination materials will be also presented using newsletters, websites and social media of related international organisations such as GSMA and the World Meteorological Organization (WMO). Dissemination will be also supported through addressing open science principles and publishing datasets and software codes in open repositories such as Zenodo resp. GitHub.

The dedicated OPENSENSE website of the Action will serve a communication channel announcing Action's activities (e.g. announcements of STSM and events) but also as an information hub on which Action social media accounts will refer to for deeper insight to the Action activates, recent findings, and outcomes. The website will include an open-access section exhibiting precipitation maps generated operationally from OS data for different regions, coupled with articles and materials aiming at different stakeholders (OS researcher, data owner, data curator, end-user, general public). The news-feed section will provide short updates and news-flash stories related to these activities (e.g. floods, new climate adaptation policies, etc.). To further enhance outreach activities and to convey the benefits of OS to the general public, the Action will update its social media accounts with regular (weekly) posts regarding precipitation monitoring and OS. A Facebook page with short vlogs and articles will also be created. The Facebook page will direct traffic to the OPENSENSE website for further reading. In addition, OPENSENSE members will be in contact with the outreach offices of their institutions, so remarkable events will be directly published in the institutions' websites, and in social media accounts (e.g. twitter, Facebook) of the institutions. In addition, outreach events including participation on European Researcher's Night and a hackathon on new applications for OS data will be organised. Traditional media will be reached through standard press releases.

Communication timeline (editorial calendar) for the Action's entire duration will be prepared at the onset of the Action. Press releases will be distributed to national media on occasion of Kick-off meeting, precipitation-related events with societal impact (floods), and/or Action outcomes with clear societal impact. Action participants will be also encouraged to actively share OPENSENSE outreach materials (and posts) on their institutional websites and social network accounts and register as experts in science media centres, which guide science journalists in identifying scientific experts for interviews on breaking news.

The impact of dissemination and project outreach will be quantified through standard indicators such as citations, number of visits and downloads, on social media number of followers, comments or retweets, and number of participants visiting events. In addition, short online surveys after workshops, training schools and final conferences will evaluate event impact as perceived by participants.

4. IMPLEMENTATION

4.1. COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1. DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

The Action objectives will be addressed by five Working Groups (WGs) which will closely coordinate their activities with each other. The agendas of the WGs 1-3 focus on the coordination of joint and synergetic research objectives. The WG4 focuses on activities increasing the Action's impact including engagement of different stakeholders, dissemination and Action communication. Finally, the WG5 addresses capacity-building objectives and coordinates WG activities to maximise Action performance and impact. WG activities consist of one or more tasks each addressing a specific research-coordination (RCO) or capacity-building objective (CBO). WGs 1-3 contribute to the dissemination of results (RCO7) by providing deliverables and publications respecting open science principles (CBO8).

WG1 on data management and standardisation

WG1 is responsible for research coordination objectives (RCO) 1 - 3 and contributes to RCO 6 and 7. It will concentrate on improving availability of well-documented OS historical and operational data and definition of benchmark datasets. Technical aspects of data curation are coordinated with WG2 and WG3, legal aspects with WG 4.

Activity 1: Curation and standardisation of individual datasets

- T1.1. Defining a common format for data exchange which will allow both the research community and stakeholders to efficiently store, organise and share large datasets. Defining minimal and optimal metadata standards for different sensor types (RCO 1)
- T1.2. Coordinating sharing and curation of individual datasets acquired by Action members in past and current projects (e.g. through Zenodo community repository). Coordinating (with WG4, T4.3) legal steps necessary to unlock these datasets and possibly publish them under open licence. (RCO2)

Activity 2: Compiling of (benchmark) datasets

- T1.3. Gathering an OS dataset geographically covering several neighbouring countries to enable large-scale OS validation (RCO 2)
- T1.4. Complementing (e.g. with meteo services being part of the Action) existing OS dataset with surface and radar observations from standard monitoring networks and by hydrological (esp. runoff) observations (RCO2).
- T1.5. Compiling one joint real-world benchmark dataset representing different climatic regions and a representative (sufficiently large) set of OS sensors and standard observations (RCO3)

Activity 3: Establishing operational access to OS

- T1.6. Establishing and maintaining operational access to OS data from at least two regions/ countries (RCO6).

WG2 on method and software homogenisation

WG2 is responsible for RCO 4 - 5 and contributes to RCO7. It will coordinate comparison and homogenisation of methods needed for operationalisation of OS precipitation observations with focus on i) automated quality control, ii) fast processing, and iii) uncertainty assessment.

Activity 1: Coordinating software community development

- T2.1. Collecting and reviewing existing OS packages and codes developed by individual research groups and initializing and managing community development of open software implementations of algorithms for processing OS observations (RCO5)

Activity 2: Coordinating joint research agenda on OS processing, quality control and uncertainty assessment

- T2.2. Coordinating comparison of fast processing and quality control algorithms suitable for operational use. Identifying benchmark algorithms (RCO4).

T2.3. Connect researchers investigating different OS sensor types and coordinate development of methods for OS processing, quality control and uncertainty assessment of OS observations utilizing also data from existing observation networks (RCO5).

Activity 3: Training PhD students and ECIs

T2.4. Organising and leading Training School on data acquisition and OS processing (CBO5)

WG3 on merging and application

WG3 is responsible for RCO 6 and 8 and contributes to RCO 3 and 7. WG3 will coordinate the research agenda on merging different types of OS with each other and with traditional observations. It will coordinate the creation of OS precipitation products in historical and operational mode and their application in weather and hydrological forecasts. WG3 will apply the joint software from WG2 and also contribute to the validation of benchmark datasets gathered and selected by WG1.

Activity 1: Merging OS observations and creating precipitation products

T3.1. Coordinating research agenda on merging OS and standard observations (RCO6)
T3.2. Coordinating creation of transboundary precipitation product from past observations (RCO2)
T3.3. Coordinating validation of benchmark datasets compiled by WG1 (through comparison of OS and standard precip. products) (RCO3)
T3.4. Coordinating creation of operational OS precipitation product (RCO6)

Activity 2: Supporting OS application in precipitation nowcasting and hydrological modelling

T3.5. Coordinating case studies demonstrating application of OS observations and precipitation products in precipitation nowcasting, and hydrological modelling (RCO8)
T3.6. Organizing and leading a Training School on OS application targeted at ECIs and stakeholders in operational hydrology/meteorology and water management (RCO7, CBO2,5)

WG4 on stakeholder involvement and external communication

WG4 coordinates stakeholder involvement and communication with external stakeholders, the scientific community, and the broader public. It develops strategies for unlocking OS data and their uptake through stakeholder engagement.

Activity 1: Involving stakeholders into Action and networking activities

T4.1. Mapping and Inviting the most relevant stakeholders in OS monitoring to join the Action (CBO2, 3)
T4.2. Surveying stakeholder needs and expectations with respect to OS. Identification of barriers preventing sensor owners to provide/share their data. Identification of issues causing mistrust to OS observations (RCO9, CBO3)
T4.3. Organizing round tables and stakeholder meetings bringing together OS data owners and end-users to discuss (business) models, which would motivate sharing of OS observations and their acceptance by end-users (RCO9)

Activity 2: Disseminating results and information on OS datasets and precipitation products

T4.4. Communicating results towards the community around satellite precipitation missions e.g. through participation in conferences of the World Meteorological Organization or participation in meetings of the International Precipitation Working Group or the Coordination Group for Meteorological Satellites. Involving them in a project on the use of OS for validation and calibration/improvement of algorithms for precipitation satellite observations (RCO8, CBO3)
T4.5. Organizing publication of works presented at Action's Workshops and the Final Conference (RCO7, CBO2)

T4.6. Assisting in implementation of open-science principles, e.g. maintaining Zenodo community repository, publishing software codes e.g. on GitHub, publishing in open access journals (CBO8)

Activity 3: Communicate Action's results to broader audience

T4.7. Establishing an Action's communication channels including website and social media accounts and administering their content. This will be done in cooperation with setting up the open community platform in WG5, which will host this website as a landing page (RCO7).
T4.8. Coordinating outreach activities including communication through social media and YouTube stream (3.2.2.), (RCO7)
T4.9. Coordinating participation in outreach events aiming at laypersons (e.g. European Researcher's Night) and organizing a hackathon on smart application of OS precipitation data

WG5 on capacity building, knowledge exchange, and coordination
WG5 manages internal communication, knowledge exchange and capacity building. It is also in charge of coordinating Working Group cross-activities, identifying possible synergies and thus maximizing the Actions impact.

Activity 1: Fostering internal communication

T5.1. Establish Action's communication channels. Create an open community platform using github and the github-pages feature, which will be managed by a small governance panel of the Action members that handle the contributions which can be submitted by everybody (CBO1, 4)
T5.2. Moderating short online Action conferences (e.g. 2 hours, 3 contributions + discussion) on quarterly basis to facilitate knowledge exchange between the groups and experts in different fields (wireless communication, hydrology, meteorology) (CBO1, 2)

Activity 2: Coordinating collaboration

T5.3. Tracking progress of WGs, identifying bottlenecks in Action's progress and cross-activities with synergistic effects (e.g. between data and method development) (CBO1)

T5.4. Collecting OS related research challenges identified by other WGs. Tracing and documenting opportunities for new opportunistic sensors and techniques and evaluating their potential for precipitation and weather monitoring. (RCO10, CBO1)

T5.5. Connecting experts (individual research groups) with potential to address new research challenges identified during the course of the Action and/or challenges which could be addressed thanks to progress in OS. Identifying international research calls suitable for addressing these challenges and coordinating preparation and submission of joint research proposal in international calls (RCO10)

Activity 3: Coordinating networking

T5.6. Coordinating Short-Term Scientific Missions with the focus on ITC and NNC countries and announcing opportunities for other non-COST fellowships (CBO5-7)
Coordinate Workshops and the Final Conference in terms of their content (RCO7, CBO5,7)

4.1.2. DESCRIPTION OF DELIVERABLES AND TIMEFRAME

The major deliverables of the Action are outputs of the activities addressing the research coordination and capacity-building objectives and can be thus used to measure progress of the Action and its success. Six milestones are identified at points where completion of one task is needed for follow-up tasks. These milestones serve as important check points mapping progress of the Action and are further discussed in the Risk analysis section (4.1.3.). They ensure coherence of the timeframe and determine due dates for completion of specific WG tasks. Both milestones and deliverables will be checked on follow-up MC and WG meetings (4.1.4).

The MC and WGs will be established at the Kick-Off Meeting. **The first year** of the Action is dedicated mainly to establishing internal and external communication channels and management platforms, and mapping and involving relevant stakeholders. The Workshop 1 at the end of the first year will serve as an important knowledge-exchange and networking event suitable for connecting researchers focusing on different types of OS (CMLs, PWS, broadband satellites) and other stakeholders. First STSM will be approved and completed in the fourth quartile of this year. **In the second year**, large-scale OS datasets will be compiled, which will enable compilation of benchmark datasets and extensive comparison of candidate algorithms for benchmarking. Furthermore, it will enable starting tasks on generation of trans-boundary precipitation products. Availability of new extensive OS dataset will also facilitate involvement of external stakeholders into OS application research, e.g. community around precipitation satellite missions. This involvement will be reinforced by Training School on OS data processing. Benchmark datasets and algorithms identified at the end of the second year represent an important milestone enabling rigorous evaluation of new algorithms. First set of STSM completed represents an important milestone for evaluating the impact of Action's networking activities. **In the third year**, generation of a trans-boundary precipitation product from OS represents a milestone in application of OS for meteorological and hydrological tasks (runoff modelling, nowcasting). This milestone is also important for external communication of OS potential and for marking up strategies for unlocking OS data. Workshop 2 will be thus more oriented towards OS application. WG 5 will also coordinate submitting a research proposal into an international call in the third year. Operational access to OS data established in **the fourth year** will enable generation of an operational OS precipitation product and it will stimulate application of OS in operational hydrology and meteorology. The Training School will be thus oriented on stakeholders interested in OS application in operational hydrology and/or water management. Strategies for unlocking OS data and upscaling OS weather monitoring will be finalised. Final conference planned for the last quartile will be a closing event of the Action summarizing main outcomes and outlining strategies for maintaining collaborations and datasets after the duration of the Action.

Deliverables assigned to specific WG tasks are listed below. Deliverables marked by bold numbering will be reported, the rest of them are internal and are included into the MoU to indicate how the Action progress will be tracked. In addition, collaboration within the Action members is expected to result from second year on to 3-5 journal papers per year covering OS topics such as fast processing, quality control, uncertainty assessment, merging with traditional observations, benchmarking, and application of OS data in hydrological modelling or nowcasting. These publications will help to monitor progress and success in reaching capacity-building objectives by tracking e.g. number and scope of publications in each year, ranking of journals, involvement of ECIs, whether the papers follow open science principles, etc. These publications are, however, not presented as deliverables. Timeframe for providing deliverables is outlined in the Gantt diagram.

Deliverables of Working Group 1 on data management and standardisation
D1.1 - Repository for individual OS datasets accessible in private and public mode
D1.2 - White paper on data standards and formats for CMLs, personal weather stations, and broadband/broadcast satellite terminals
D1.3 - Three individual datasets (CML, PWS, BBS) documented and shared in the repository
D1.4 - Large-scale OS dataset complemented with standard observations and documentation in the form of a report
D1.5 - Benchmark dataset representing different climatic regions and documentation in the form of a report
D1.6 - Documentation for accessing operational OS data including terms of service from at least two regions/countries

Deliverables of Working Group 2 on method homogenisation and new sensing opportunities
D2.1 - Guidelines for contributing to Git repository
D2.2 - Content for training school on OS processing published at the website
D2.3 - First release of community software package with processing and quality control algorithms

D2.4 - Report documenting benchmark algorithms on fast processing and quality control suitable for operational use
D2.5 - New release of OS processing package based on the development and coordination with the Action

Deliverables of Working Group 3 on operationalisation and application
D3.1 - Opportunistic sensing precipitation product validated using traditional observations and published as a dataset
D3.2 - Content for Training School on OS application published at the website
D3.3 - Report documenting case studies and other applications of OS datasets compiled by the Action
D3.4 - Operational opportunistic sensing precipitation product available as case study demonstrator for hydrological application

Deliverables of Working Group 4 on external communication, dissemination and stakeholder involvement
D4.1 - Editorial calendar for external communication
D4.2 - Action communication channels including website and social media accounts with specific content
D4.3 - Report evaluating survey on stakeholders needs and expectations with respect to opportunistic sensing
D4.4 - Report evaluating impact of dissemination and outreach activities
D4.5 - Special issue on operational precipitation opportunistic sensing, nowcasting and hydrological forecast in a scientific journal
D4.6 - Description of the financial benefits and reasonable business models for monetising OS data and technologies

Deliverables of Working Group 5 on capacity-building, knowledge exchange, and coordination
D5.1 Community platform with github and gitlab-page features established and administrators elected
D5.2 Content for Workshop 1
D5.3 Content for Workshop 2
D5.4 Content for Final Conference

4.1.3. RISK ANALYSIS AND CONTINGENCY PLANS

The progress of the work on different tasks will be closely monitored by WG leaders who will report unforeseen circumstances to the MC committee. The MC committee and WG leaders will discuss specific steps to mitigate unforeseen failures and, if necessary, develop a new strategy for reaching the objective in an appropriate and timely manner. The major risks and mitigation actions are listed in the following table:

Risk	**Probability**	**Impact**	**Mitigation action**
Relevant stakeholders not involved into Action	Low	High	Inviting external stakeholders to Action meetings and events ad hoc
OS data for compiling large-scale OS dataset cannot be shared due to legal constraints	Moderate	Moderate	Anonymisation of data e.g. by changing position of end nodes. More focus on synthetic datasets.
Benchmark dataset cannot be gathered	Low	Moderate	Use existing open OS dataset (despite they have limited extent)
Quality control and retrieval algorithms do not provide adequate accuracy to improve traditional monitoring networks	Low	High	Focus on regions with sparse or no traditional measurements
Low number of STSM or their inadequate impact	Low	Moderate	Better promotion of STSM, improving selection criteria

Transboundary OS precipitation product cannot be compiled	Mode-rate	Mode-rate	Compilation of local/regional precipitation products
Operational access to OS data cannot be established	Mode-rate	Mode-rate	Use of historical OS datasets to simulate operational use of OS
Key persons are missing on the meetings	Mode-rate	Low	Action involves a sufficient number of experienced researchers to replace missing persons
Cancellation of Action meetings with personal participation due to ongoing Covid-19 pandemic	High	Low	Transformation of the meetings, workshops and training schools in online mode

4.1.4. GANTT DIAGRAM

The Gantt chart shows in a tentative way the main Action's events, activities, milestones, and deliverables. Timeframe of individual WG tasks is indicated by deliverables assigned to each activity.

	year 1				year 2				year 3				year 4			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
General meetings/Networking																
Kick-off/MC+WG meetings	kc															
Action events				w1	t1					w2			t2			fc
STSMs																
WG1 - Activities for:																
Data curation			d11	**d12**		**d13**										
Dataset compilation							d14	**d15**								
Operational access to data													**d16**			
WG2 - Activities for:																
Software development				d21			**d23**									**d25**
OS processing methods									**d24**							
PhD&ECI Training School					d22											
WG3 - Activities for:																
Precipitation product												**d31**				**d34**
OS data application												d32	**d33**			
WG4 - Activities for:																
Stakeholder involvement						**d43**									**d46**	
Dissemination		d41	**d42**						d44				**d45**			
External communication							E1				E2		E3		E4	
WG5 - Activities for:																
Internal communication		d51							d53				d54			
Collaboration																
Networking			d52													
Milestones				**1**		**2**		**3,4**		**5**			**6**			

Milestones:

M1 - relevant stakeholders involved in the Action
M2 - large-scale dataset in standardised format available for benchmarking of algorithms
M3 - best-performing quality control algorithms (WG2) and merging algorithms (WG3) identified
M4 - first set of Short-Term Scientific Missions completed
M5 - transboundary OS precipitation product available
M6 - operational access to subset of OS data established

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