LIFE15/CCA/IT/000035
With the contribution of the LIFE financial instrument of the European Community

RAINBO

Deliverable 2.3
Integrated Rainfall data covering the test area

Action C2 – Study, design and implementation of the new monitoring infrastructure

Comune di Bologna
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NIER INGEGNERIA
MEEO Meteorological Environmental Earth Observation

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Document Summary

This document reports the new monitoring infrastructure of the project including the Microwave telecommunication network here used, with the conventional and existing monitoring networks.

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Summary

1. Introduction

Within the C.2 Action different monitoring network will be evaluated in order to set some preliminary evaluations about the integration between the available conventional networks and the innovative ones, such as the microwave rainfall monitoring system exploiting the microwave links used in the communication networks worldwide.

2. Available monitoring networks and data

2.1 The Microwave Rainfall monitoring network

The microwave rainfall monitoring system exploits the microwave links used in commercial cellular communication networks. Along such links, radio signals propagate from a transmitting antenna at one base station to a receiving antenna at another base station. Rain-induced attenuation and, subsequently, path-averaged rainfall intensity can be retrieved from the signal's attenuation between transmitter and receiver by applying, almost in real-time, a rainfall retrieval algorithm

The implementation of the algorithm for the specific needs of the Italian test areas, as well as code debugging and improving, is done by MEEO in close contact with the original authors (please see Deliverable 2.2 for details on the implemented procedure: RainBO_C2_2_Deliverable_RainfallDataMicrowaveLinks_02.pdf).

Microwave links data are supplied by telecommunication operators Lepida and Vodafone. High density network coverage is needed for best performances. The data consists in near real time receiving power readings, collected every one (Lepida) or fifteen (Vodafone) minutes. The algorithm works with 15-min maximum and minimum received powers, from which calculates signal attenuation estimations and, through information about the link's path-length, the instantaneous path-averaged rainfall depths.

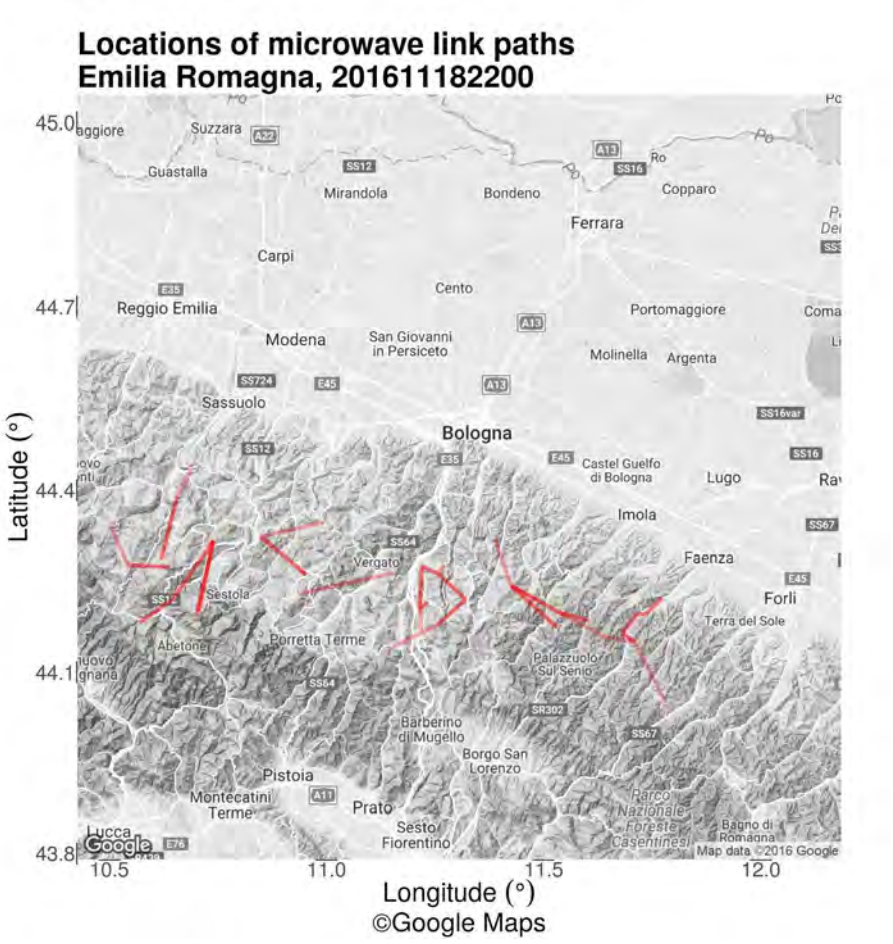
This data is then interpolated over a grid to obtain a rainfall map, applying an ordinary kriging which employs a spherical variogram model. The algorithm offers an easy setup for the interpolation parameters, allowing improvements after further studies on the precipitation mean characteristics.

Rainfall maps are delivered every 15 min with a delay of a pair of minutes of processing time (still to be tested in real-time); a daily accumulation map is produced every day. The 15 min maps are comparable with real time radar

reflectivity maps, the daily accumulated ones are comparable with rain-gauge datasets.

The available Microwave data up to this phase of the project are scarce and insufficient, as we have:

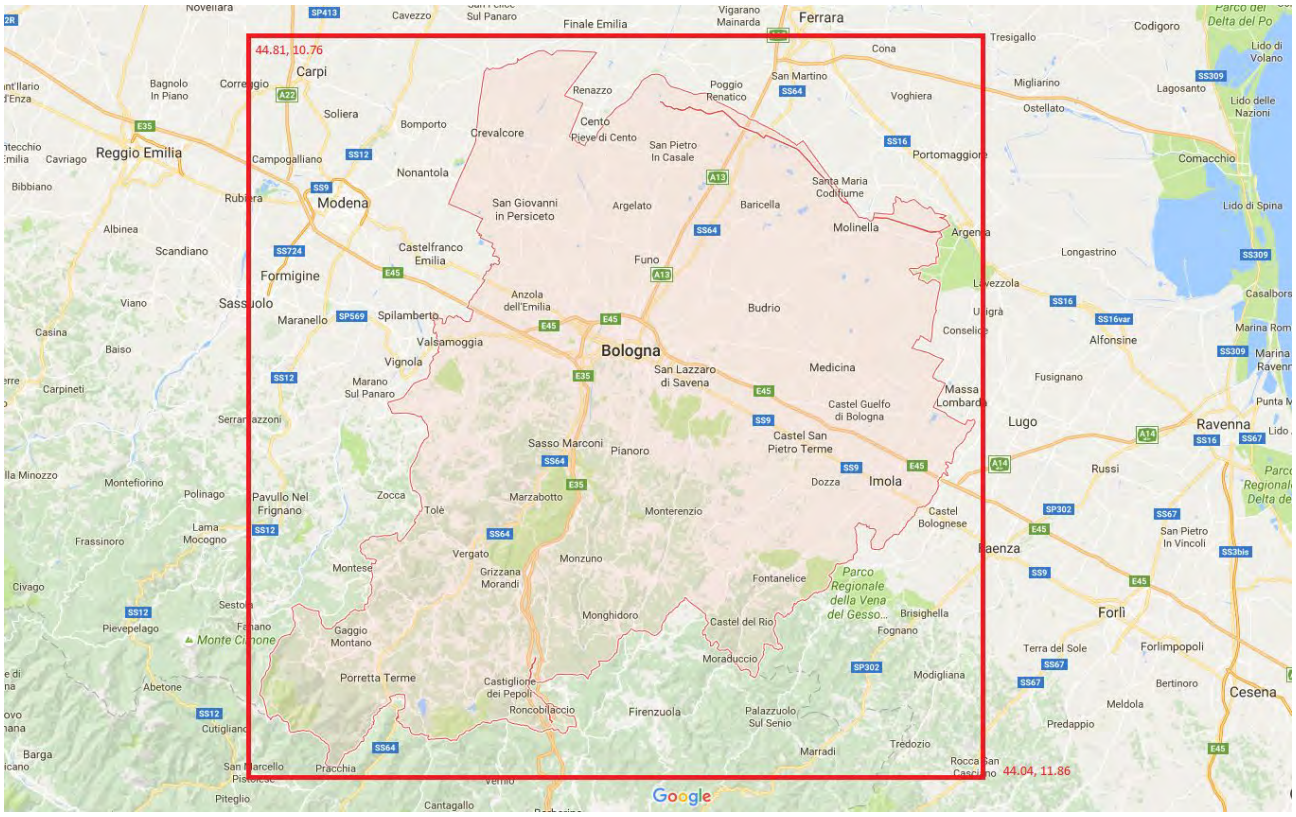
- Microwave data supplied by Lepida, covering the Apennines region of the Emilia Romagna, so outside the metropolitan areas of Bologna and Parma;

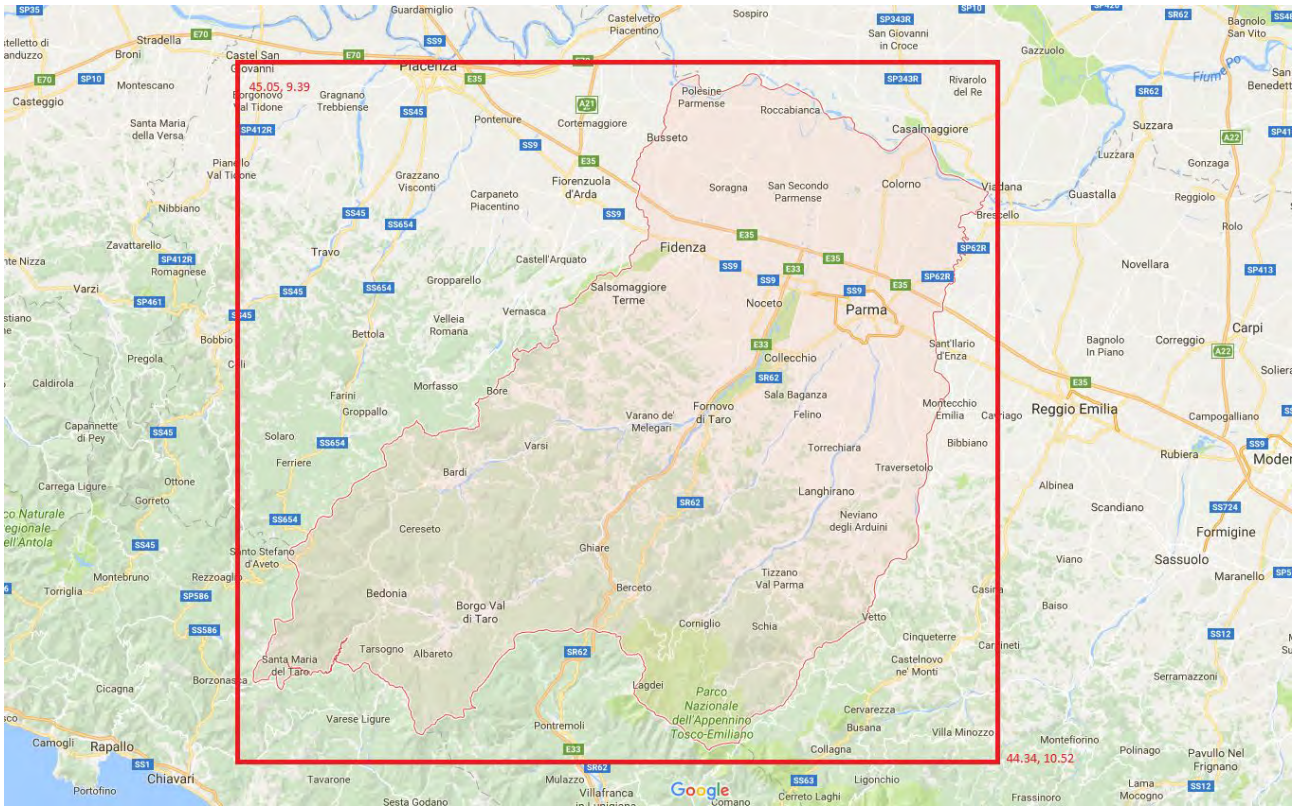


- A very limited sample of data of one day and half outside our pilot cities, useful for the tuning of the algorithm but not sufficient for the validation of the integrated method.

Starting from March 2017, we expect to receive all the Microwave data requested to cover Bologna and Parma areas, on

the following area of interest respective on Bologna and Parma provinces:





Details on the data format and the interested periods are reported in the document RainBO_data_requirements.pdf.

Please refer to the deliverable RainBO_C2_5_deliverable_ValidationPrecipitation.pdf for a final version of all the Microwave data that will be definitely provided by Vodafone and Lepida.

2.2 Conventional monitoring networks

The RIRER network as a whole

RIRER network is the Italian acronym for Emilia-Romagna integrated monitoring network managed by Arpae.

In more details, Emilia-Romagna Region owns the RIRER network from 2001 (DGR n. 2515 del 26/11/2001) to pursuant to L.R. n. 7 del 2004 – Provisions on environment, modification and integration to regional laws, where at art. 30, Arpae has the duties to manage the hydro-meteo-pluvio network system of the Region. The duty of unique manager of the hydro-meteo-pluvio monitoring network is confirmed each year by the Decision of Regional Government of Emilia-Romagna that approves the annual programme of maintenance of RIRER and the commitment of the expenditure.

RIRER network (see the table below) consists of automatic stations (254 stations with CAE technology, 60 stations with SIAP technology and 63 with Vaisala stations) and integrates the stations of regional property and other authorities (Irrigation and Land reclamation Consortia).

Property	Number of stations	Number of stations	Technology	Data transmission type
RER	312	252	CAE	Radio UHF
		60	SIAP	Radio UHF/TETRA
Arpae	63	63	Vaisala	GPRS

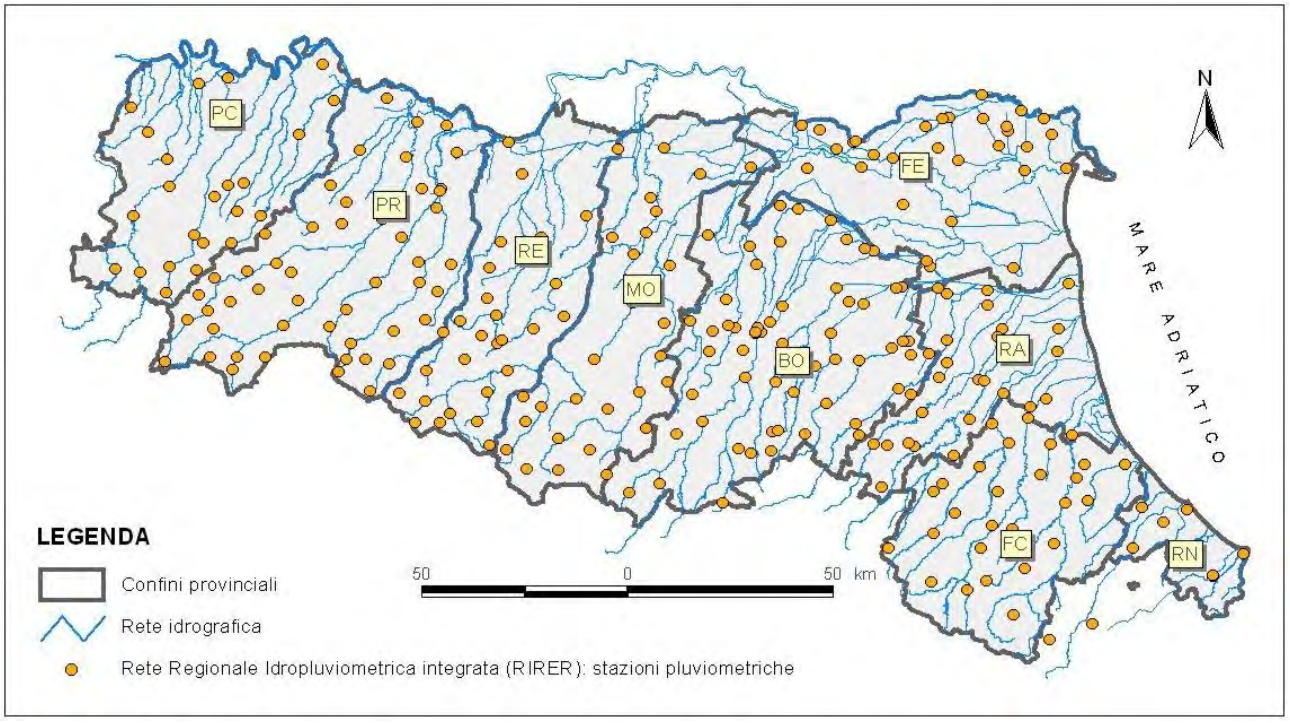
RIRER network and e Arpae: number of stations, technology and data transmission type

This network is essential for the Region, for purposes of Civil Protection, because it represents a tool to monitor the evolution of meteorological events and to assess the consequences on the anthropic systems, also by means of forecast scenarios. These evaluations provide technical support for the issues of Civil Protection alerts, then transmitted to the

Municipalities. Moreover, RIRER is a key tool for other sectors of the Region such as agriculture, environment, transports.

The hydro-pluvio stations

The hydro-pluvio stations are distributed all over the region, with a higher concentration in the regional territory between Piacenza and Bologna, whereas they are distributed to a lesser extent in Ferrara area and Romagna (see the map below). For Ferrara, this distribution is due to the lack of natural rivers, because only canals of Irrigation and Land reclamation consortia are present, that are managed by the Ferrara reclamation consortium, with a his own station network. Romagna area is covered by river network with weather stations with different technology.



Rain gauges distribution over the Emilia-Romagna region

A part of the hydro-pluvio stations is represented by a group of stations on areas out of the regional territory, but belonging to the hydrographic basins.

The stations can be mainly divided in hydrometric stations and pluviometric stations. The second group are usually equipped by other sensors such as thermometers, wind speed and direction sensors and snow height sensors. See the table below for more details.

Sensors	PC	PR	RE	MO	BO	FE	RA	FC	RN	TOT RER
Rain gauges	24	50	28	27	58	31	25	29	10	282
Hydrometric levels	19	27	22	19	50	41	36	23	5	242
Air temperatures	16	45	23	24	23	14	19	17	7	188
Wind	6	6	3	3	8	5	2	4	3	40
Sun Radiation	2	3	2	3	6	4	2	3	3	28
Air pressure	6	3	3	3	6	4	2	3	3	33
Relative humidity	8	14	7	11	14	9	9	6	5	83
Snow depth	0	2	6	3	2	0	0	0	0	13
Totals	**81**	**150**	**94**	**93**	**167**	**108**	**95**	**85**	**36**	**909**

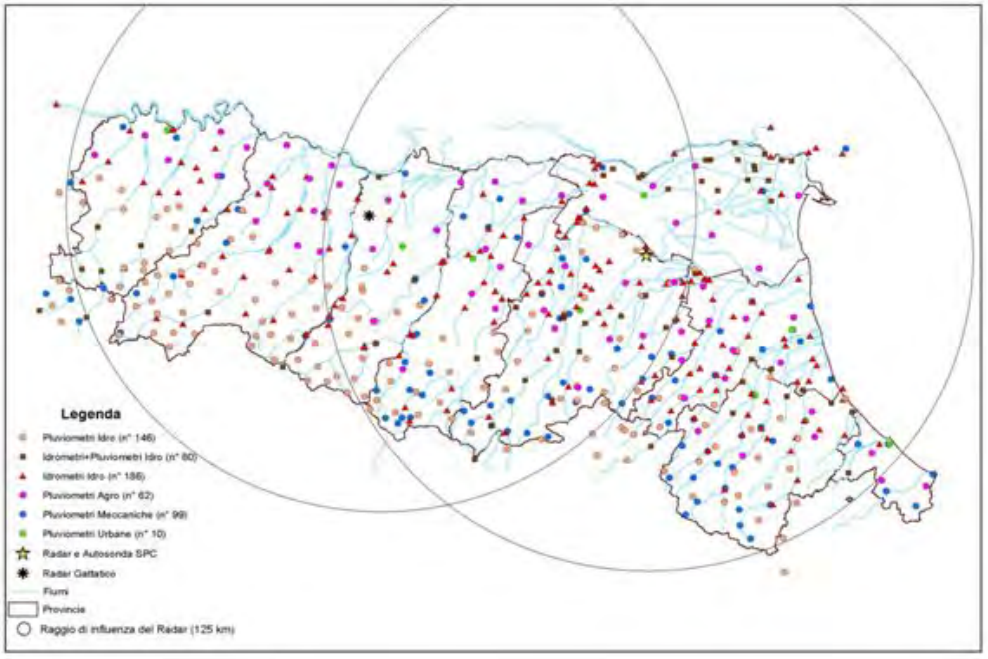
Classification of the RIRER stations by sensors type

In the table below, the consistency of the RIRER network (with CAE technology) for each province is reported, together with the extra regional stations.

Province	Nr. rain gauges	Nr. hydrometers	Nr. rain gauges + hydrometers	Total (RG+H+RGH)
PC	12	13	5	**30**
PR	33	21	1	**55**
RE	16	13	4	**33**
MO	14	16	2	**32**
BO	15	29	10	**54**
FE	1	9	2	**12**
RA	0	6	3	**9**
RN	1	2	3	**6**
Extra RER	16	5	2	**23**
Total	108	114	32	**254**

The RIRER network (with CAE technology) for each province

The field sensors measure data with continuity, the values are averaged to provide instant estimates (e.g. each 30 minutes or 60 minutes) or summed to evaluate the cumulated data (e.g. precipitation each 30'). The data measured by sensors are elaborated in a control unit installed in every stations.



The RIRER network

Radar

Two radars are located in Emilia-Romagna: in San Pietro Capofiume (BO) and in Gattatico (RE), see the figure above where the spatial domain (a radius of 125 km) of the two devices is reported. Every 15 minutes, the radars provide reflectivity data that are processed by several algorithms to correct the main known issues: soil echoes caused by non meteorological factors, abnormal propagation. The reflectivity value, expressed in dBZ, is directly related with the cloud water content and it corresponds to the precipitation. It is possible also to relate the value in dBZ and the instant precipitation, expressed in mm/h, with the following relation:

<10 dBZ	=	<0.2 mm/h (no rainfall)
10-20 dBZ	=	0.2 mm/h (at times)
20-35 dBZ	=	1-6 mm/h (weak)
35-45 dBZ	=	6-25 mm/h (mean)

45-55 dBZ = 25-100 mm/h (heavy)

>55 dBZ= >100 mm/h (intense)

The maps produced by the radar provide an estimation of the precipitation value, that varies over time and space.

2.3 Sensornet platform

RainBO system collects data coming also from the Lepida regional platform called Sensornet, which integrates more that 1500 heterogeneous sensors distributed on the Emilia Romagna Region and it collects data regarding the following monitoring environmental data:

- Water level
- Rain gauges
- Landslides
- Traffic
- Different meteorological parameters

2.4 Participative network

RainBO is connected to the Rmap system which collects further meteorological data mainly on:

- Snow
- Rainfall
- Wind
- Temperature
- Humidity

The data are supplied in a standard WMO format by the following possible bodies:

- Environmental Protection Agencies
- Meteorological offices
- Research Centers

- Citizens

The data will be uploaded to the system by using a web interface or a mobile app developed during Rmap project (http://rmap.cc/) and improved and optimized during RainBO LIFE project in order to foster the involvement of citizens in supplying useful data in order to enrich the meteorological database available for the project.

3. Preliminary feasibility study of the data integration

A preliminary feasibility study has been conducted in February during C2 action by MEEO and Arpae, considering the available data described above.

Comparisons with hydrological information and radar reflectivity maps show good correlation in time and raw correlation in space, and tests show that the algorithm works best with short high density links that cross each other, but a more reliable and accurate study has to be postponed to the next months when we expect to receive data from Vodafone in order to cover the metropolitan areas of Bologna and Parma.

So far, only Microwave data from Lepida are available but with a limitative coverage of our pilot areas as they collected data on the Appennino area.

For the tuning of the Microwave rainfall map algorithm, also some data coming from Vodafone was used but they were not covering project pilot area and they represented only a sample of 2 days data.

The data coming from Vodafone will allow the punctual comparison with the relative rainfall data measured by the rain gauges along the Microwave links path.

3 Next steps

The data integration evaluation process will be managed for the whole project even during C4 action, as we expect that the test and validation operations through Bologna pilot case could provide important elements to better define a more mature integrated monitoring system.

The new monitoring infrastructures, after April 2017, will include a crowdsourcing component (the optimized Rmap app) that makes possible the retrieval of citizens data and their sharing towards all the interested actors (Municipality of

Bologna, Arpae, Emilia-Romagna region etc.), citizens included.

4 Reference documents

The description of the implemented algorithm for Microwave link rainfall map is reported in the deliverable **RainBO_C2_2_RainfallDataMicrowaveLinks_02.pdf**

The area of interest, period and details of the data format for Microwave link data to be collected are reported in the document RainBO_data_requirements.pdf

The deliverable **RainBO_C2_4_CrowdSourcing.pdf** describes the participative or crowdsourcing system that allows to collect data on the present weather and its impact.

Please refer to the deliverable **RainBO_C2_5_ValidationPrecipitation.pdf** for a final version of all the Microwave data that will be definitely provided by Vodafone and Lepida and that will be used in the validation activity.

Please refer to the deliverable **RainBO_C2_6_DataCollection.pdf** for details regarding the software package used to collect the Lepida and Vodafone data.