CIMO TECO 2018

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A field assessment of a novel rain measurement system based on satellite-to-earth microwave links

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ARTYS

Spin off Università degli Studi di Genova

University of Genova

WMO Lead Centre *B.Castelli*

1. **OBJECTIVE**
2. THE MEASURING SYSTEM
3. THE EXPERIMENTAL SET-UP
4. PRELIMINARY RESULTS
5. FUTURE DEVELOPMENTS

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OBJECTIVE

- To **exploit existing technologies and infrastructures** to complement traditional monitoring networks with **real-time information** on the time/space evolution of the **atmospheric precipitation field**;

- To test the satellite microwave link technique, **Smart Rainfall System - SRS**, by means of a comparative experimental campaign in the city of Genoa (Italy)

- To build-up an **extensive data-set covering at least two years of observations** in the test area of Genoa (Italy).

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CONTEXT

The **Department of Naval, Electrical, Electronic, and Telecommunications Engineering (DITEN)** of the University of Genova is providing a scientific background to the development of advanced data processing of the DVB-S signal.

Artys srl is a startup company founded as a spin-off of the University of Genova, after a cooperation with Darts Engineering and the departments DITEN and DICCA of the university.

Spin off
Università degli Studi di Genova

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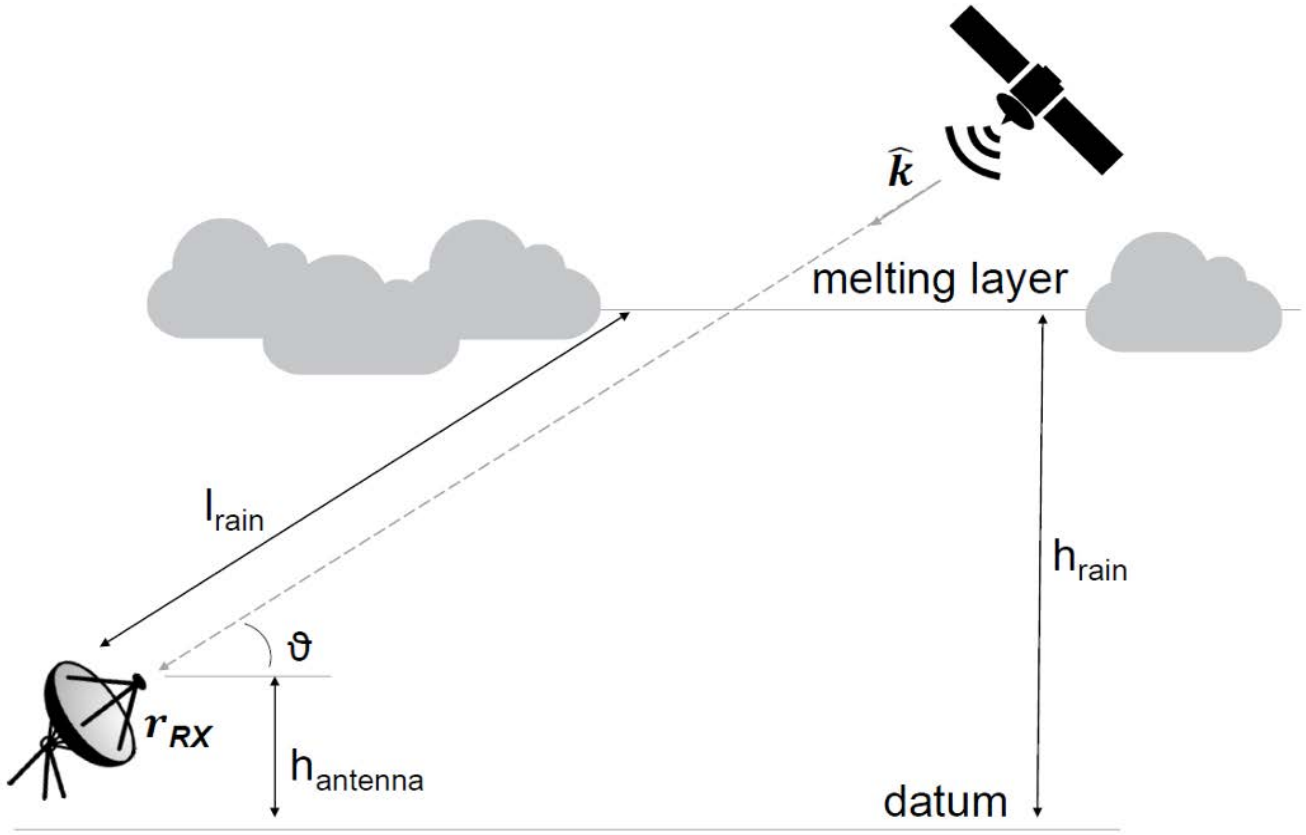
RAIN ESTIMATION APPROACH (1/4)



Smart Rainfall System – SRS exploits satellite microwave links by measuring the power of the digital television DVB-S signal transmitted in the Ku band.

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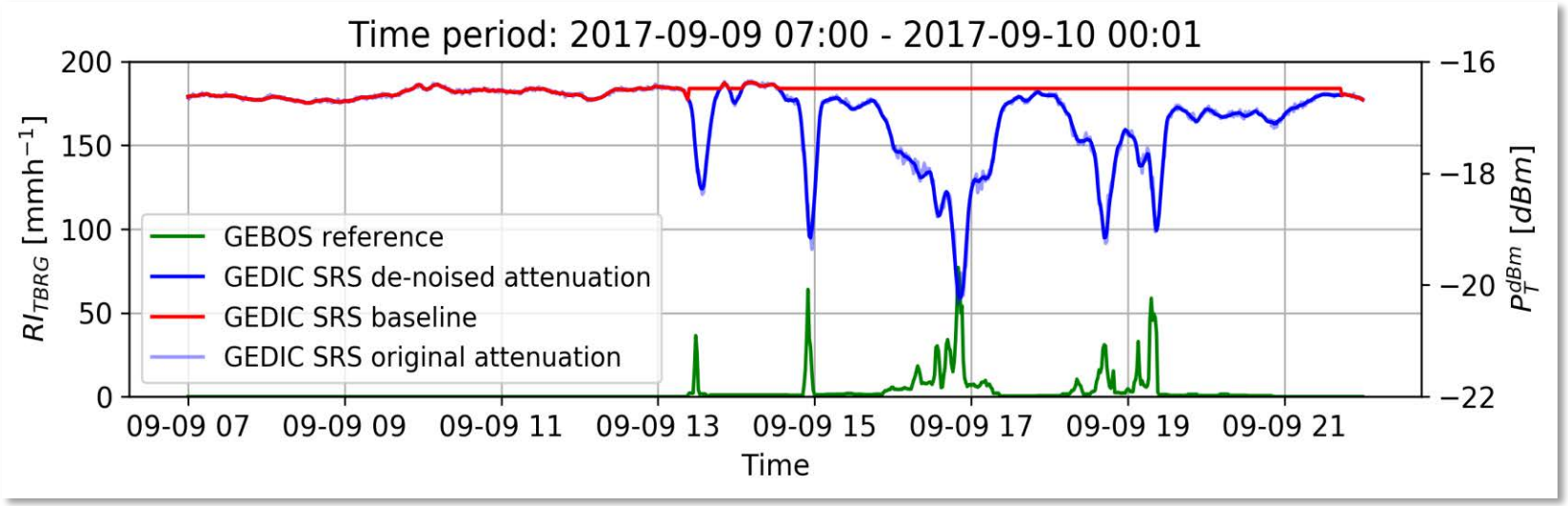
RAIN ESTIMATION APPROACH (2/4)

- The output of the antenna (and consequently of the sensor) is related to the rain rate R by the following relationship (derived from the ITU model [*])

$$P_T = P_0 \cdot e^{-b \cdot RI^a \cdot l}$$

- v_0 is the baseline (i.e., the output without rain)
- *a* and *b* are two parameters of the ITU model, which depend upon the wave polarization
- *l* is the part of the patch connecting the satellite to the RX station laying beyond the melting layer



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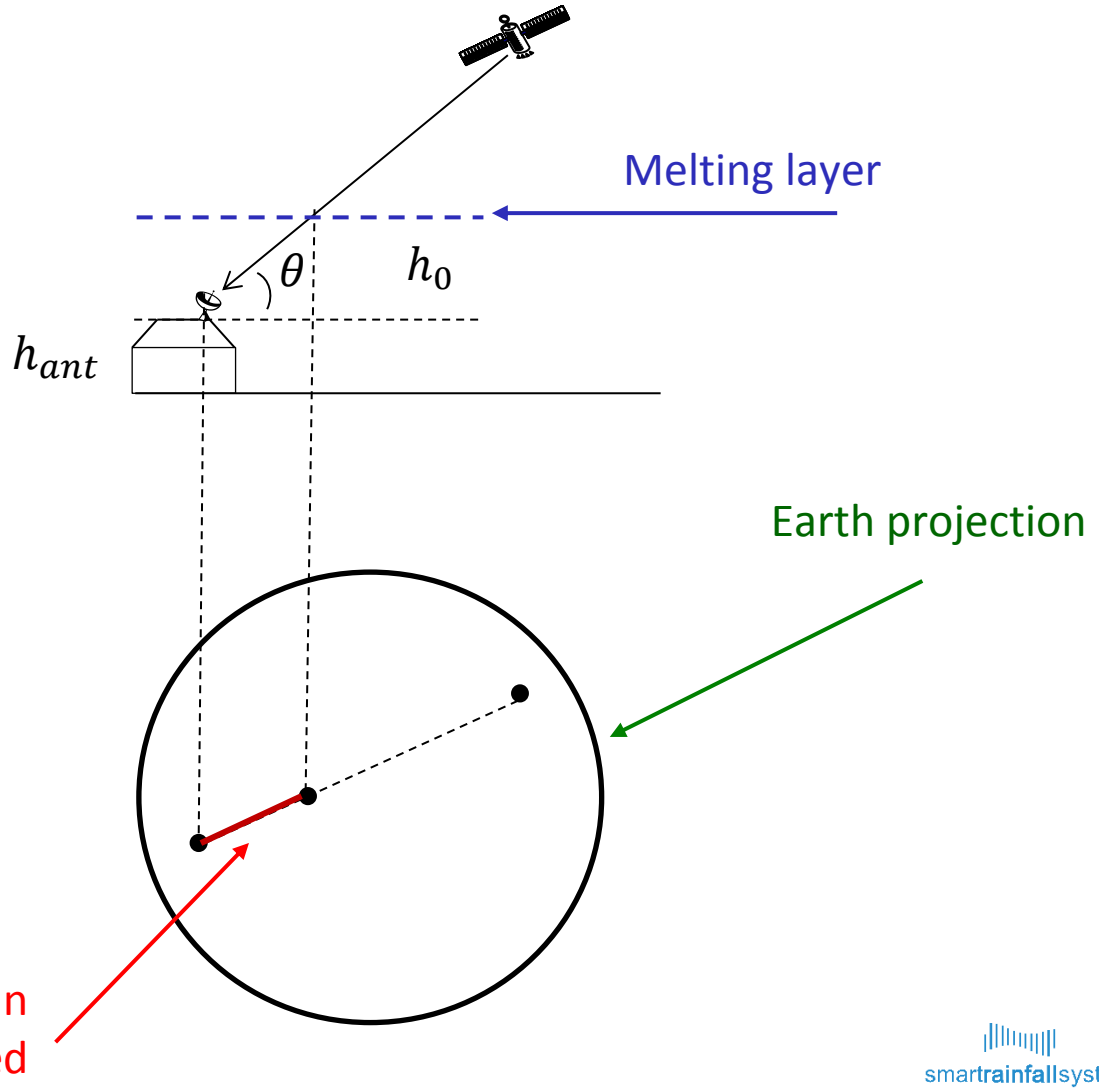
RAIN ESTIMATION APPROACH (3/4)

- The path to the melting layer can be computed from the knowledge of the geographical positions of RX antenna and satellite, i.e.,

$$l = \frac{h_0 - h_{ant}}{\sin\theta}$$

- Finally the rain rate below the path to the zero isotherm is obtained as

$$RI\,(t) = \sqrt[a]{\frac{1}{bl}\ln\left(\frac{P_0}{P_T}\right)}$$



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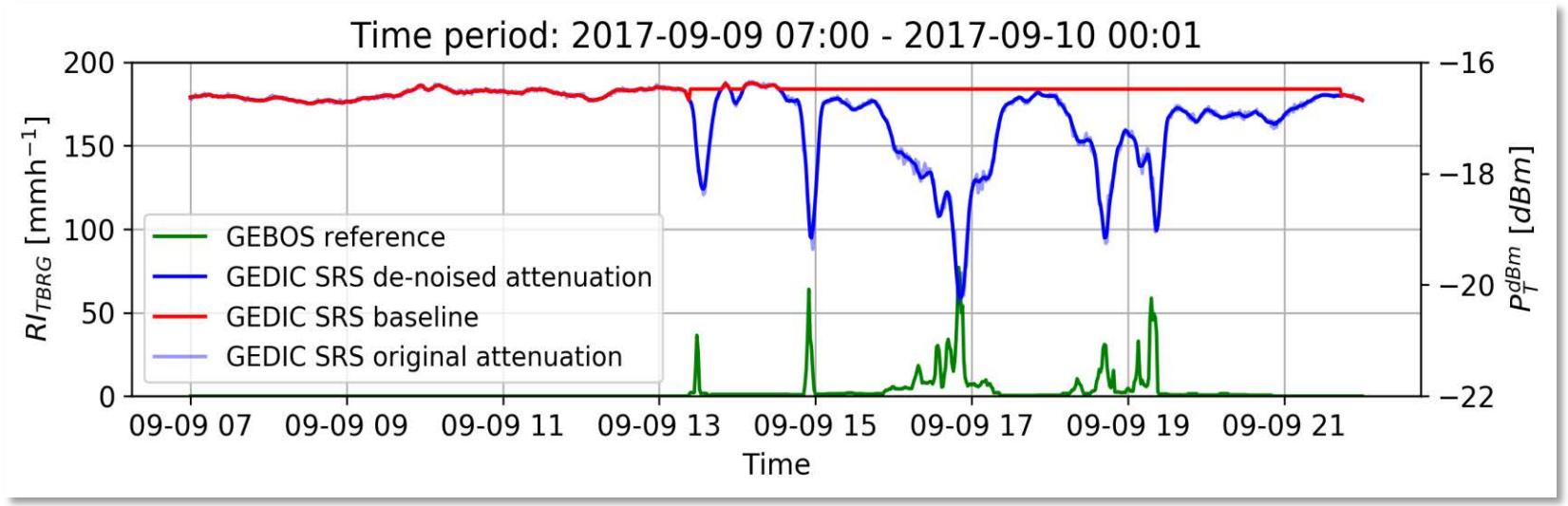
RAIN ESTIMATION APPROACH (4/4)

Experimentation:

Collecting sets of measures in the Genoa test-bed in various weather conditions

Prototype validation:

Through the comparison between the measurements of the Smart Rainfall System and those of a reference rain gauge, under different atmospheric conditions



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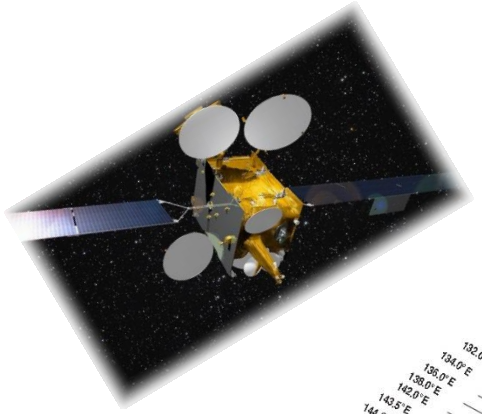
SYSTEM ARCHITECTURE 1/4



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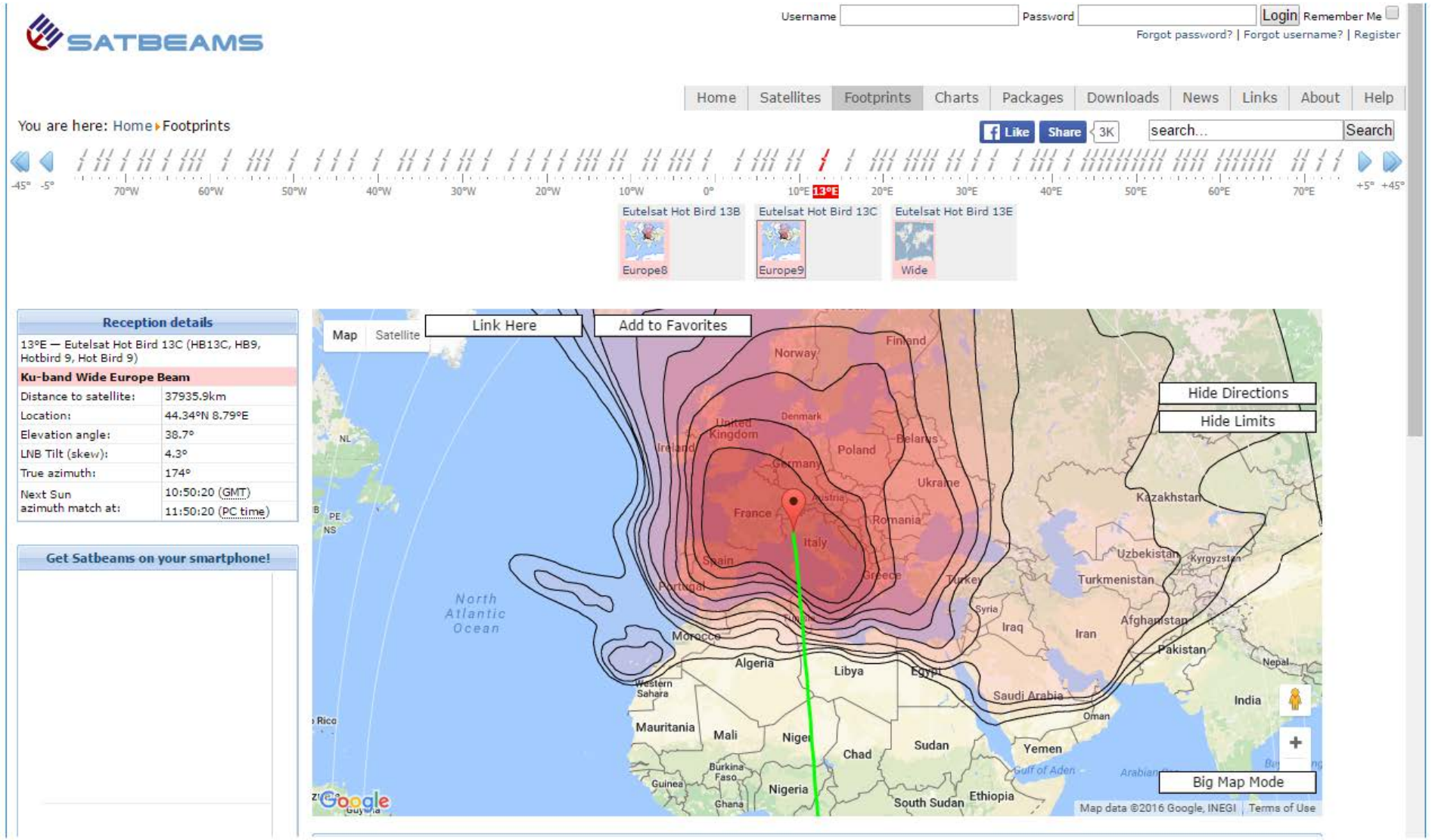
SYSTEM ARCHITECTURE 2/4



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SYSTEM ARCHITECTURE 3/4

Network tailoring:

- Depending on the **orography of the territory** the network is designed for the best combination of:
  - *Layout of the **Measurement sites***
  - *Number and direction of **antennas** at each site*

to optimize **the coverage of hydrographic basins**

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SYSTEM ARCHITECTURE 4/4

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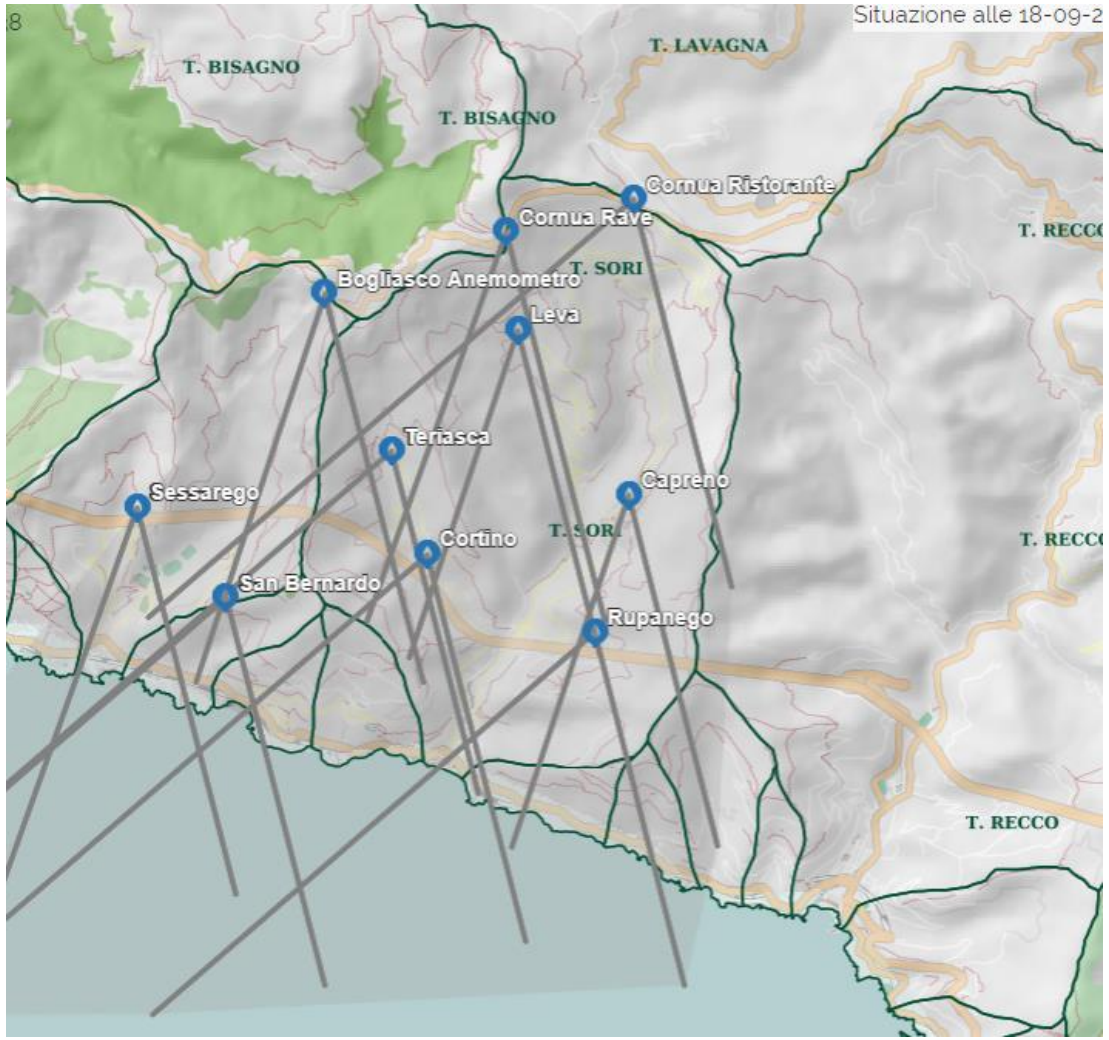

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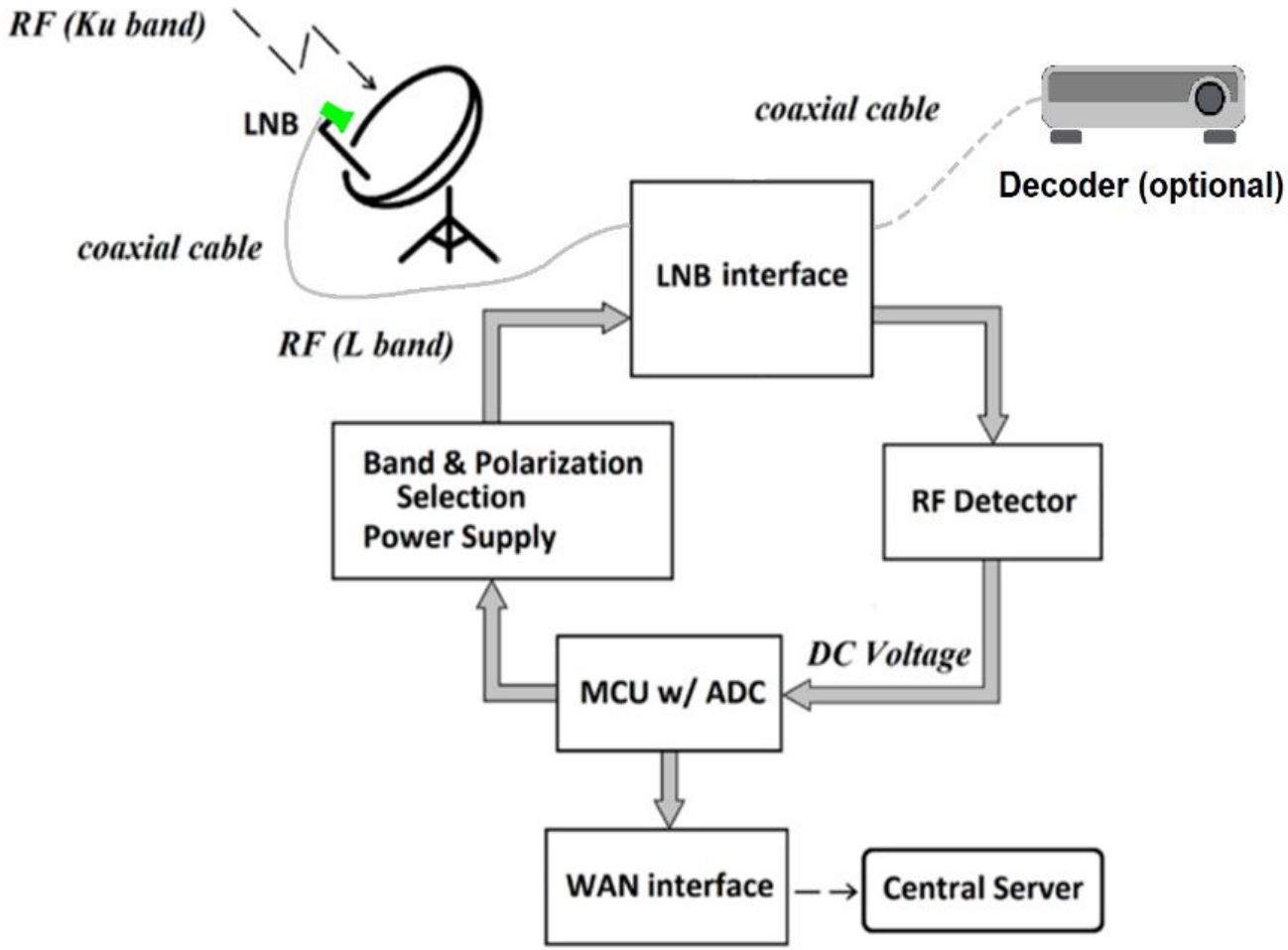
SENSOR UNIT (1/2)



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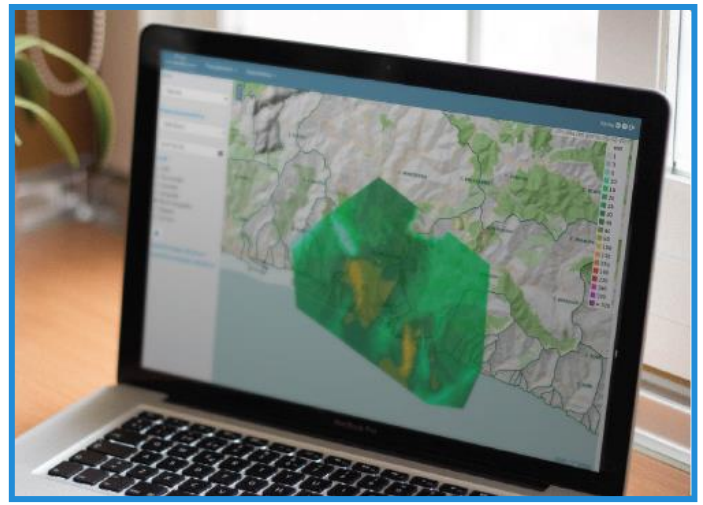
SENSOR UNIT (2/2)

Satellite TV antenna

SRS box

webGIS server



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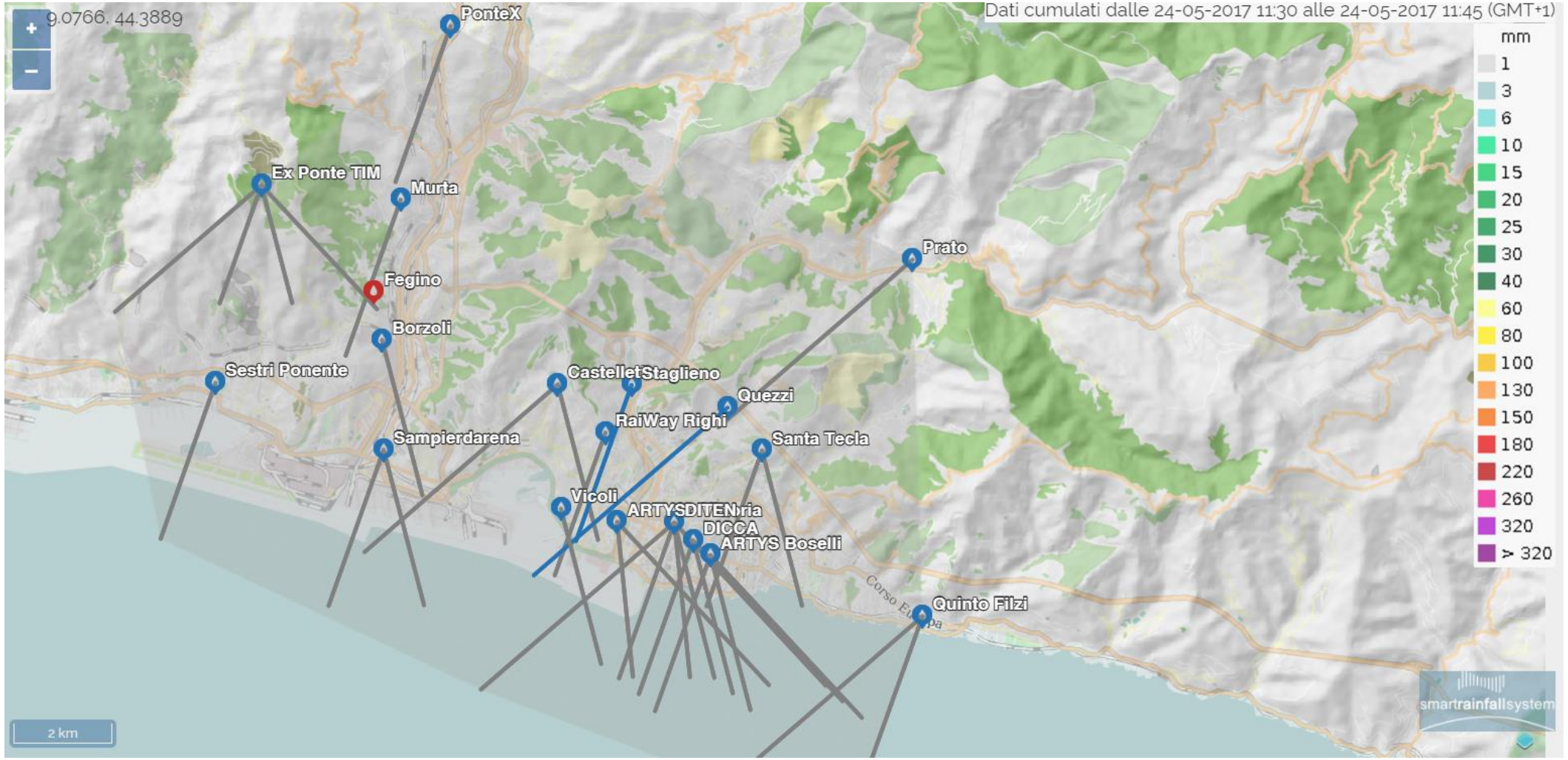
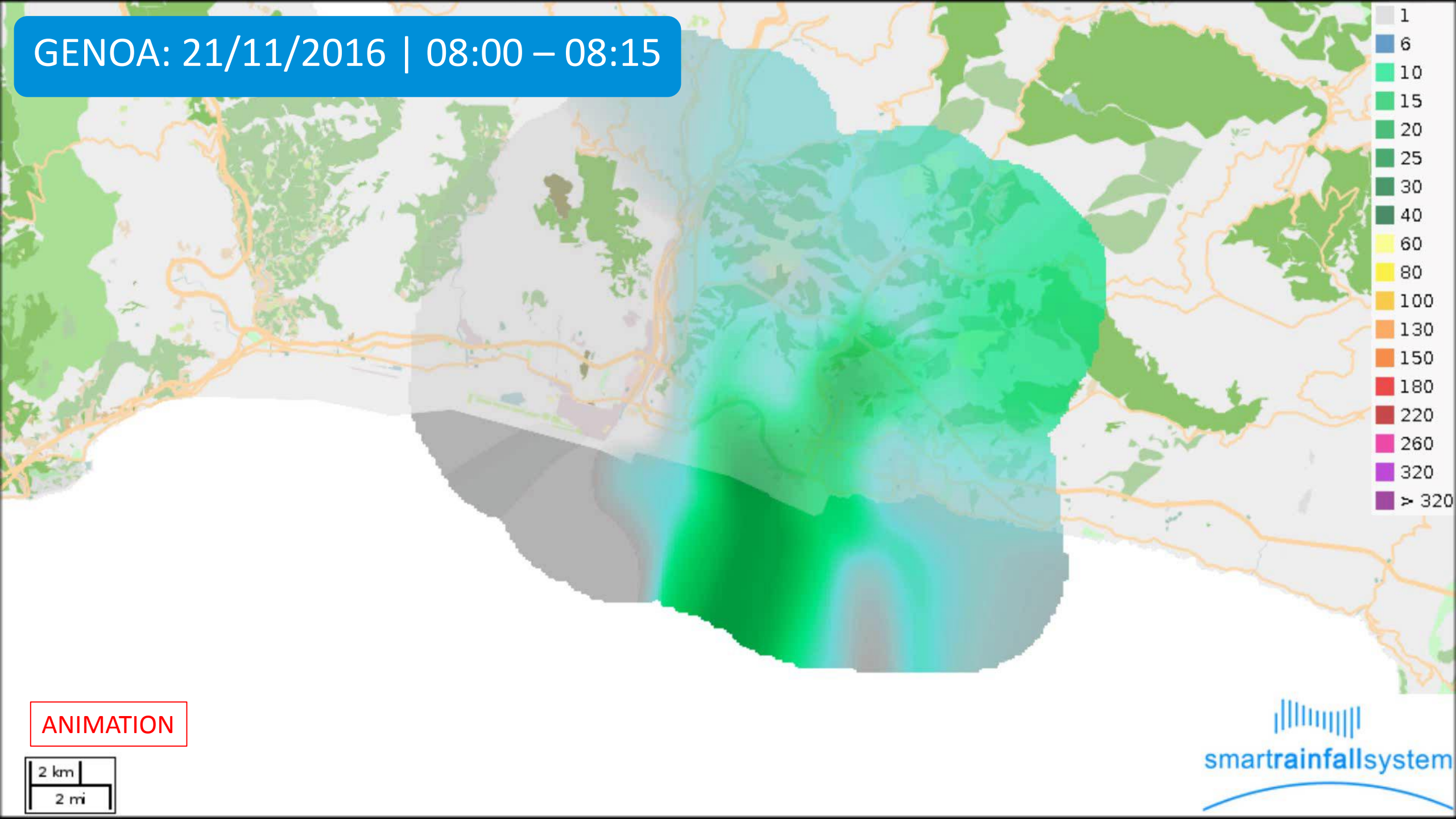
SRS – GENOA EXAMPLE




GENOA: 21/11/2016 | 08:00 – 08:15
1
6
10
15
20
25
30
40
60
80
100
130
150
180
220
260
320
> 320
ANIMATION
2 km
2 mi
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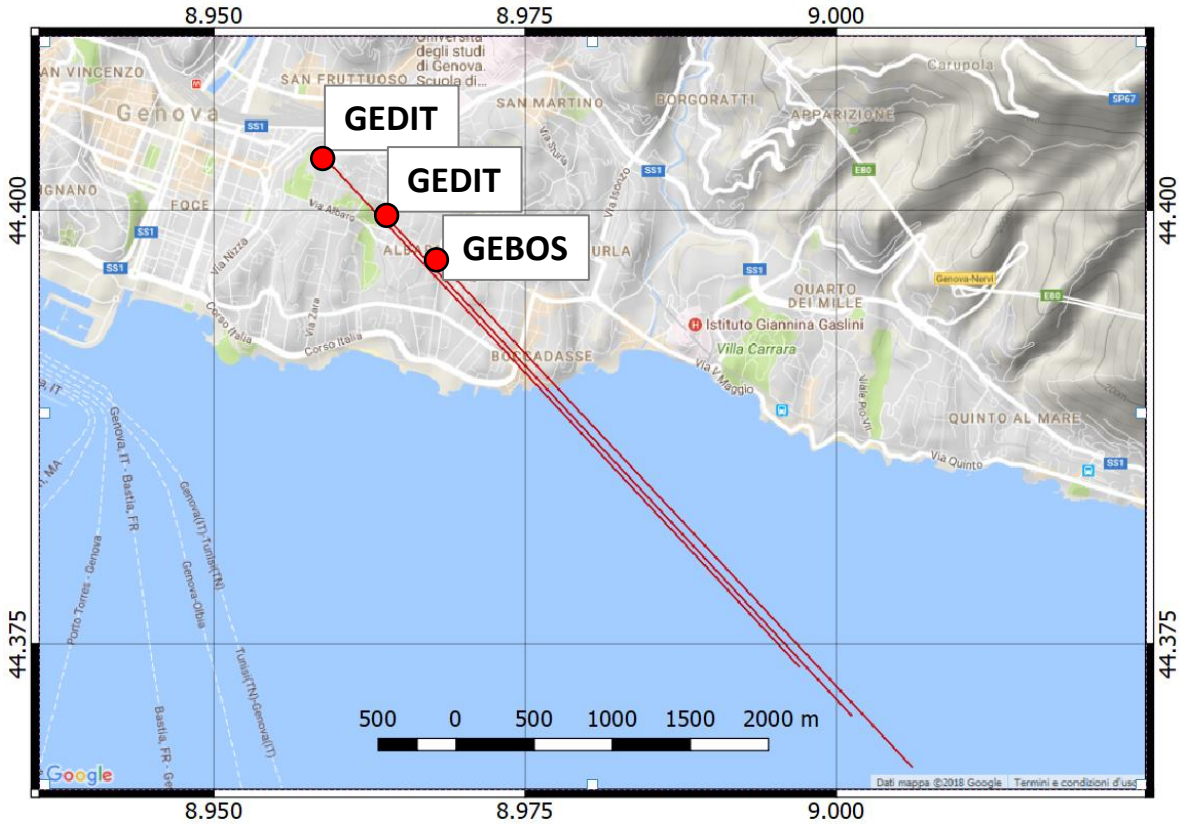
FIELD EXPERIMENT (1/6)

Genoa, the experimental set-up

- The comparative field experimental set-up consists of three SRS sensors, that receive the satellite digital video broadcasting signal emitted by Turksat 42 E° in the upper Ku band with vertical polarization. Each site is equipped with a low-cost parabolic dish of 60 cm of diameter and a universal Low Noise Block filters.



Field test-bed in the City of Genoa (Italy)

Colli et al. 2018 - IEEE Transaction on Geoscience and Remote Sensing, minor review

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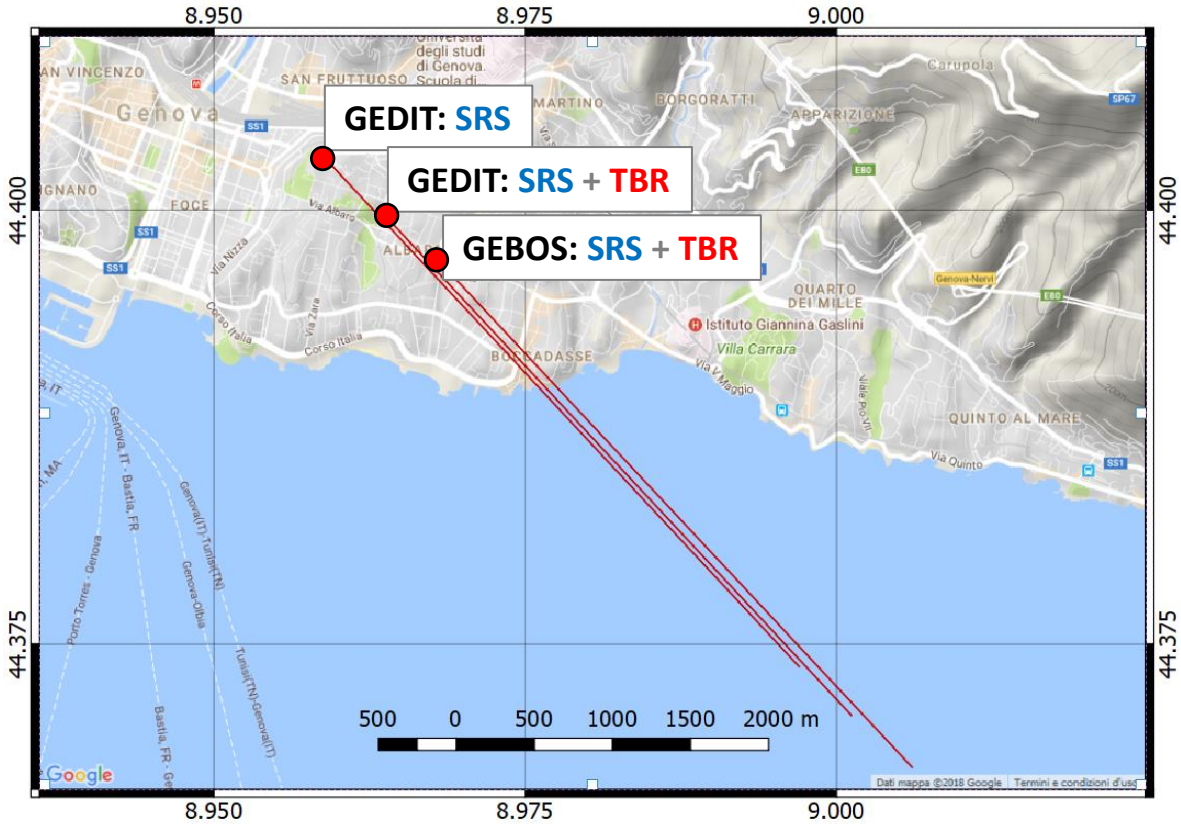
- Reference measurements are made by two tipping-bucket rain gauges (TBR) calibrated by the WMO – Lead Centre *B.Castelli* Precipitation Intensity laboratory.

Site code	Latitudine	Longitudine	Altitude [m]	Instruments
GEDIT	44.4031	8.9587	70	SRS
GEDIC	44.3998	8.9636	40	SRS + TBR
GEBOS	44.3972	8.9679	65	SRS + TBR



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FIELD EXPERIMENT (1/6)

Genoa, the experimental set-up

Most significant precipitation events occurred in Genoa (Italy) from Nov. 2016 to Jan. 2018 and observed by the reference TBR (GEDIC site)

Event ID	Selected for analyis	Day	h *mm*	max(RI) *mm/h*	d *minutes*
Ev01	Yes	25/11/2016	33,6	61,2	226
Ev02	Yes	05/02/2017	37,5	24,3	561
Ev03	Yes	11/07/2017	25,7	273,8	61
Ev04	Yes	22/07/2017	34,1	113,3	99
Ev05	Yes	09/09/2017	54,1	123,3	368
Ev06	Yes	05/11/2017	49,6	124,4	386
Ev07	No	11/12/2017	66,4	53,7	1145
Ev08	Yes	27/12/2017	45	58	481
Ev09	Yes	01/01/2018	32,7	52,7	369
TOTAL	--	--	378,6	--	3696
TOT. selected	--	--	312,2	--	2551

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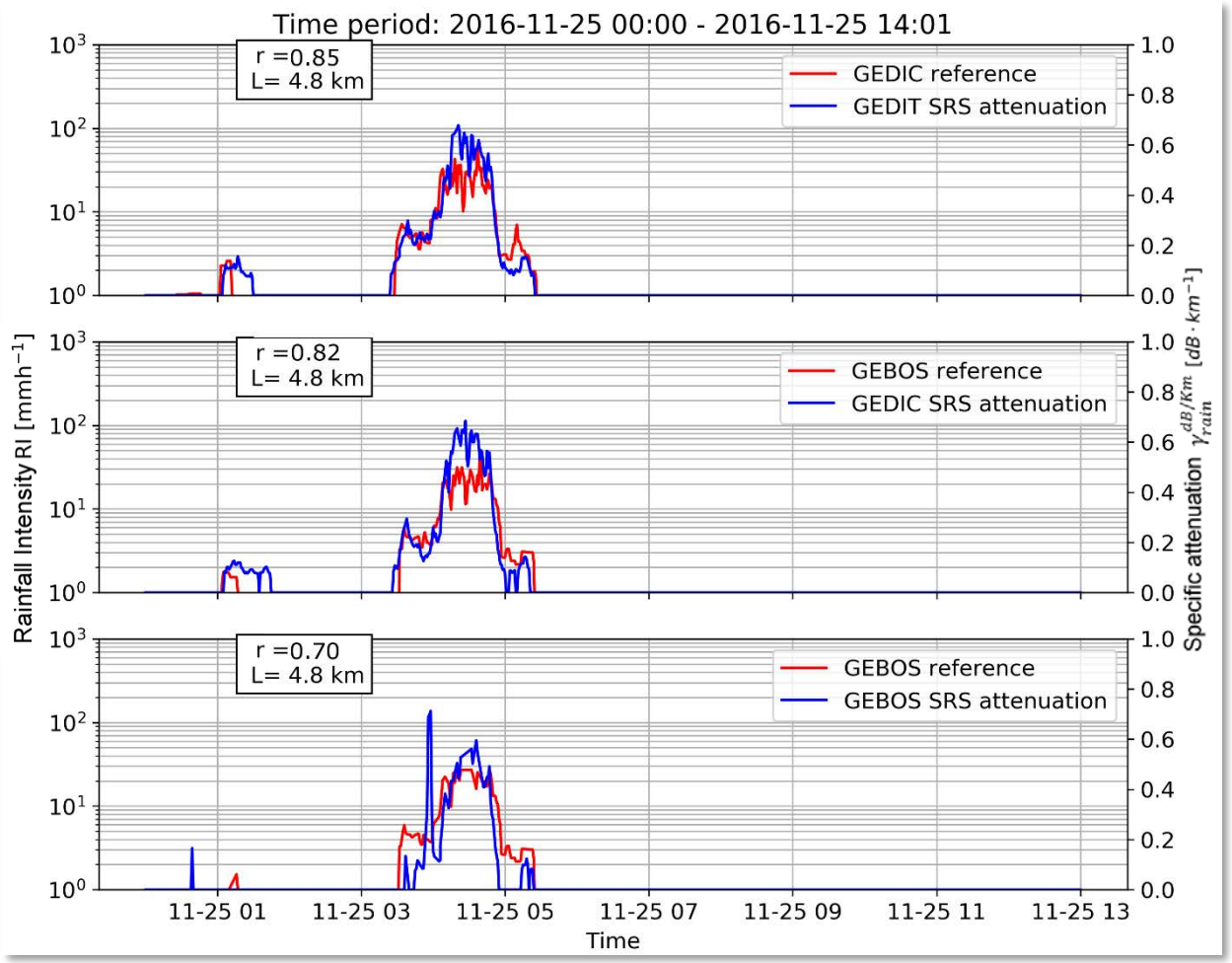
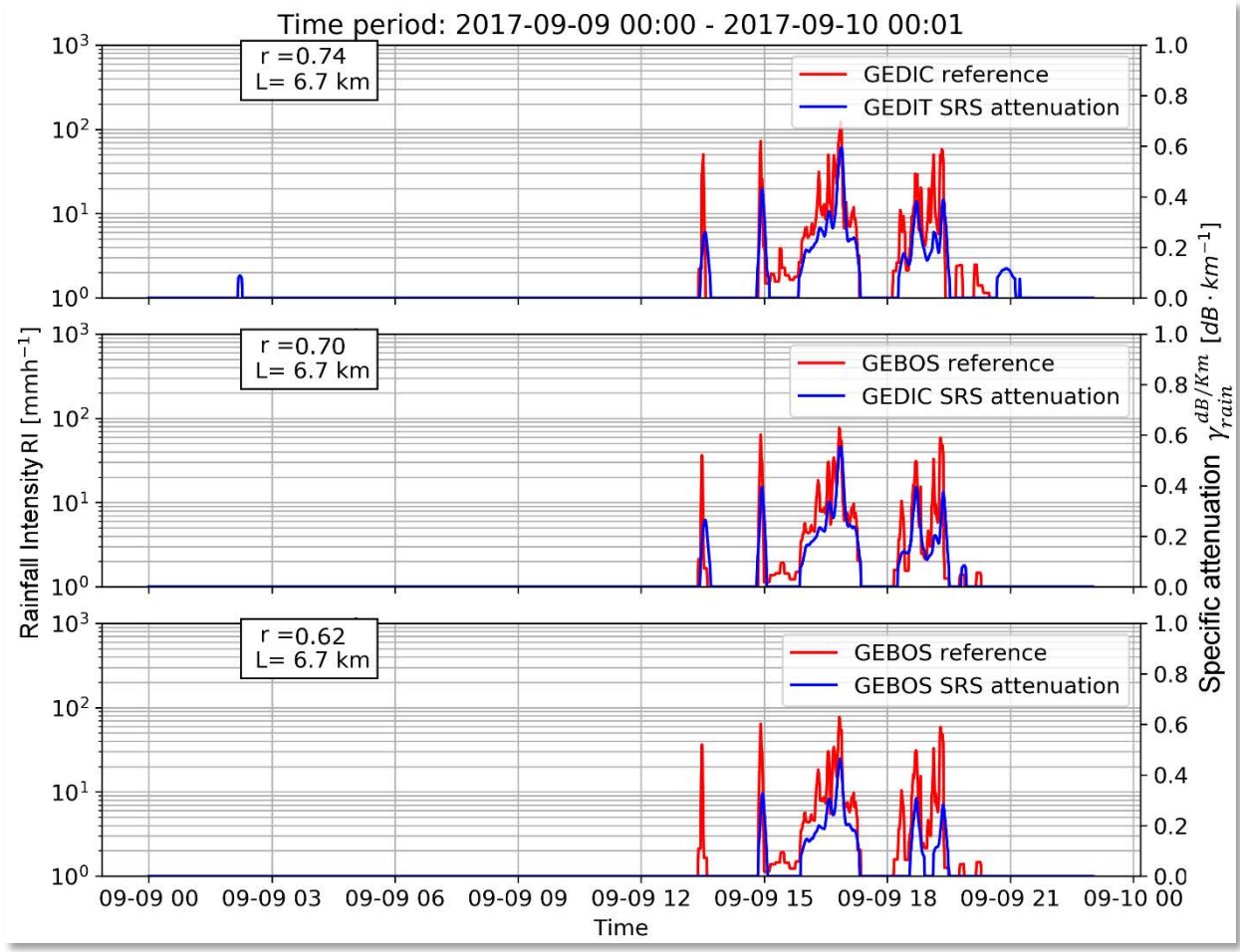
FIELD EXPERIMENT (2/6)

1-min reference rainfall intensity vs specific attenuation





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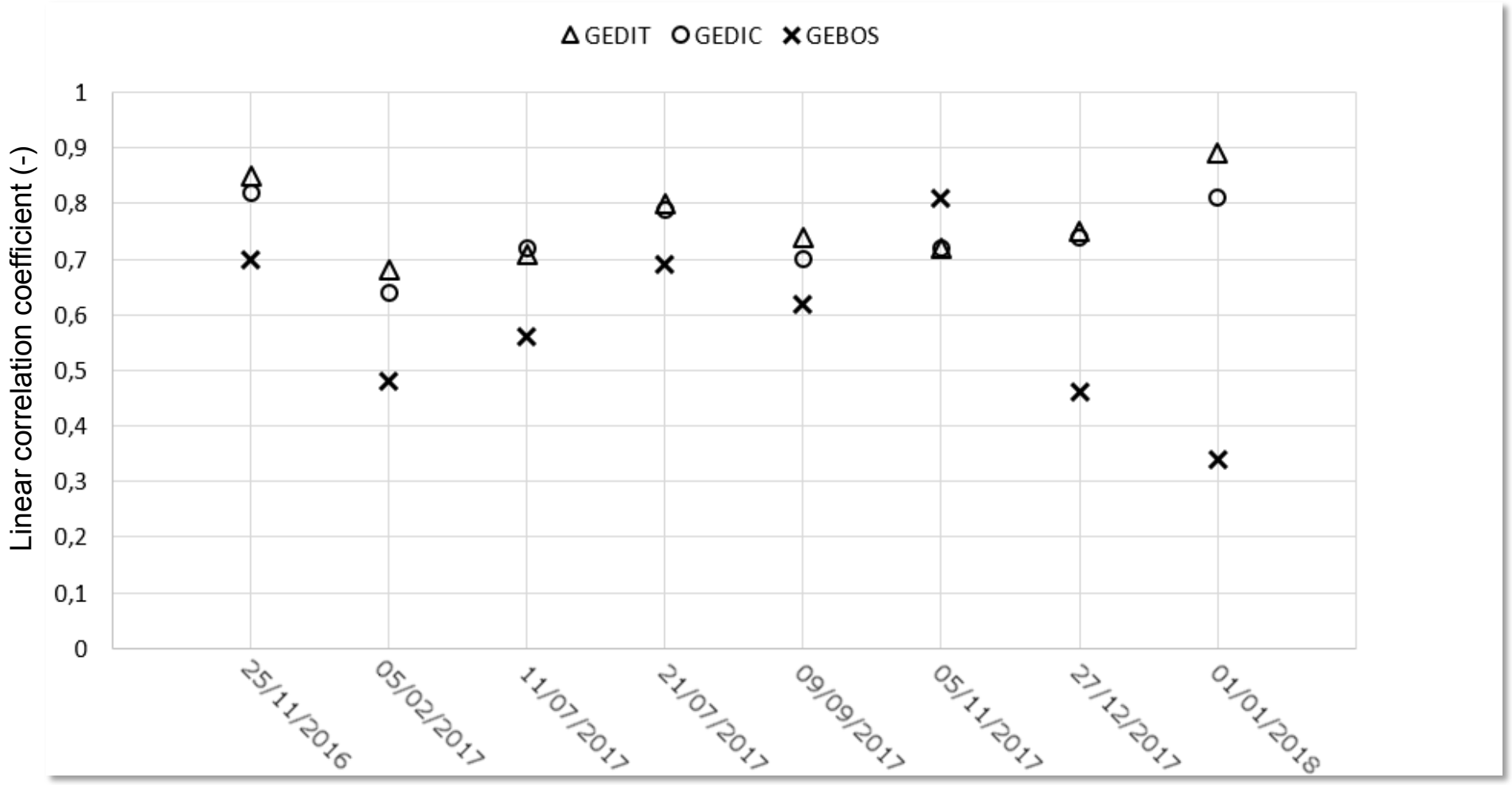
FIELD EXPERIMENT (3/6)

Linear correlation between 1-min reference vs. SRS rainfall intensity



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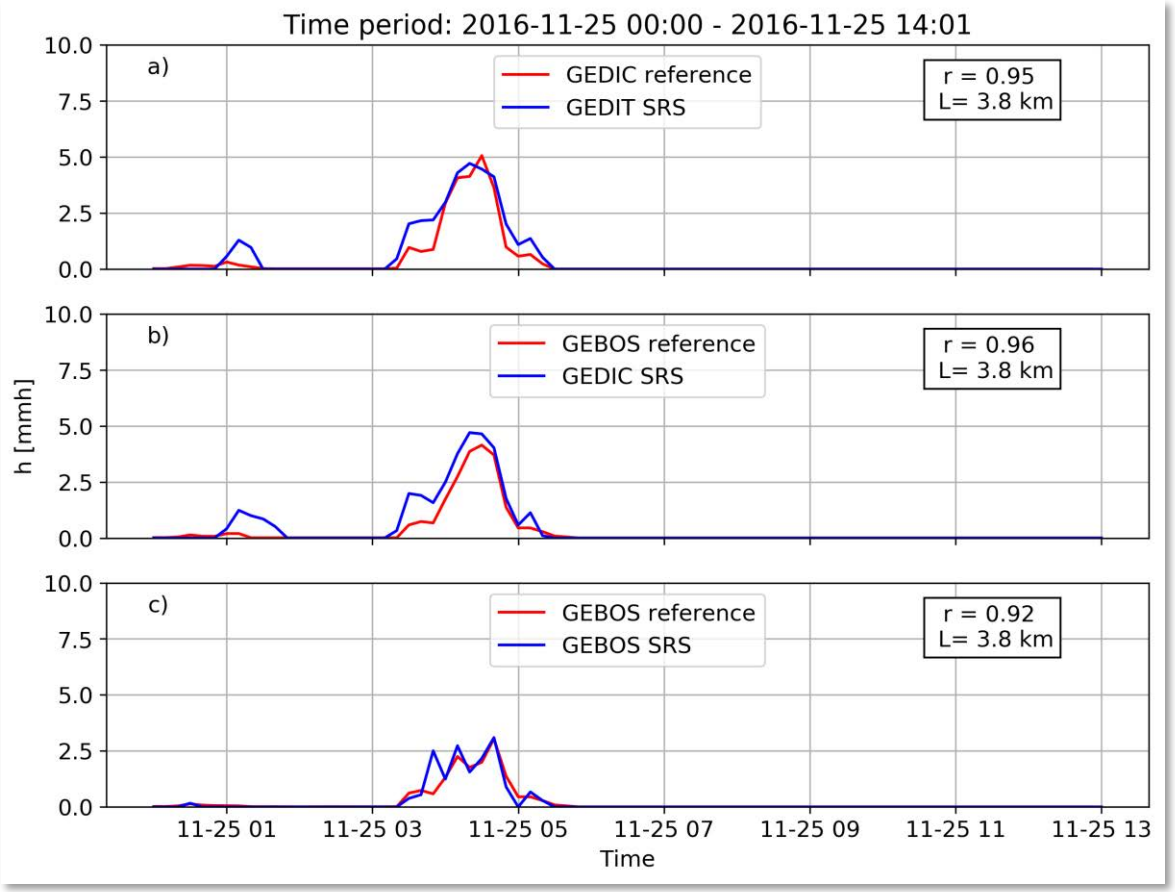
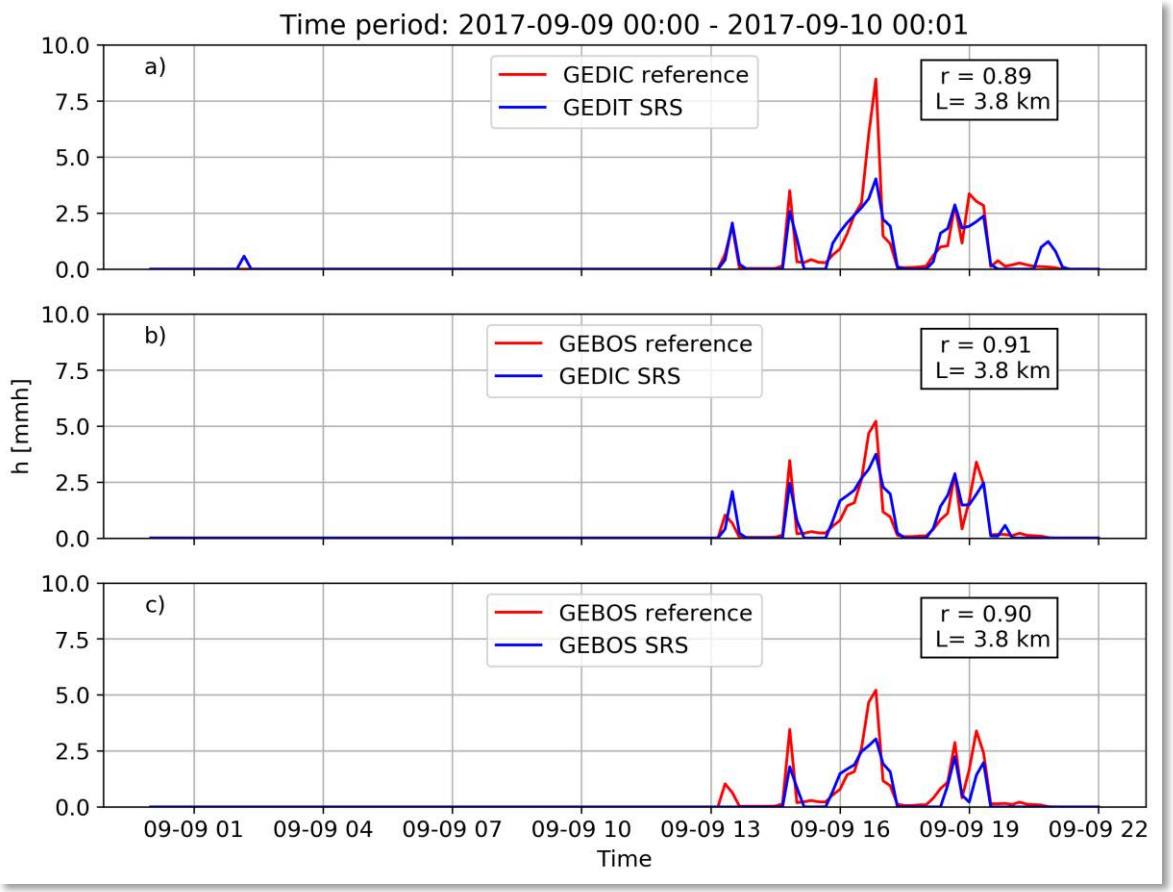
FIELD EXPERIMENT (4/6)

10-min reference vs. SRS rainfall amount





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FIELD EXPERIMENT (5/6)

10-min SRS rainfall intensity vs. reference measurements

REFERENCE		GEBOS SRS	
		RAIN	NO RAIN
	RAIN	11.2	6.4
	NO RAIN	1.3	81.2

REFERENCE		GEDIT SRS	
		RAIN	NO RAIN
	RAIN	16.9	2.1
	NO RAIN	2.1	78.9

REFERENCE		GEDIC SRS	
		RAIN	NO RAIN
	RAIN	15.7	2.1
	NO RAIN	3.5	78.7

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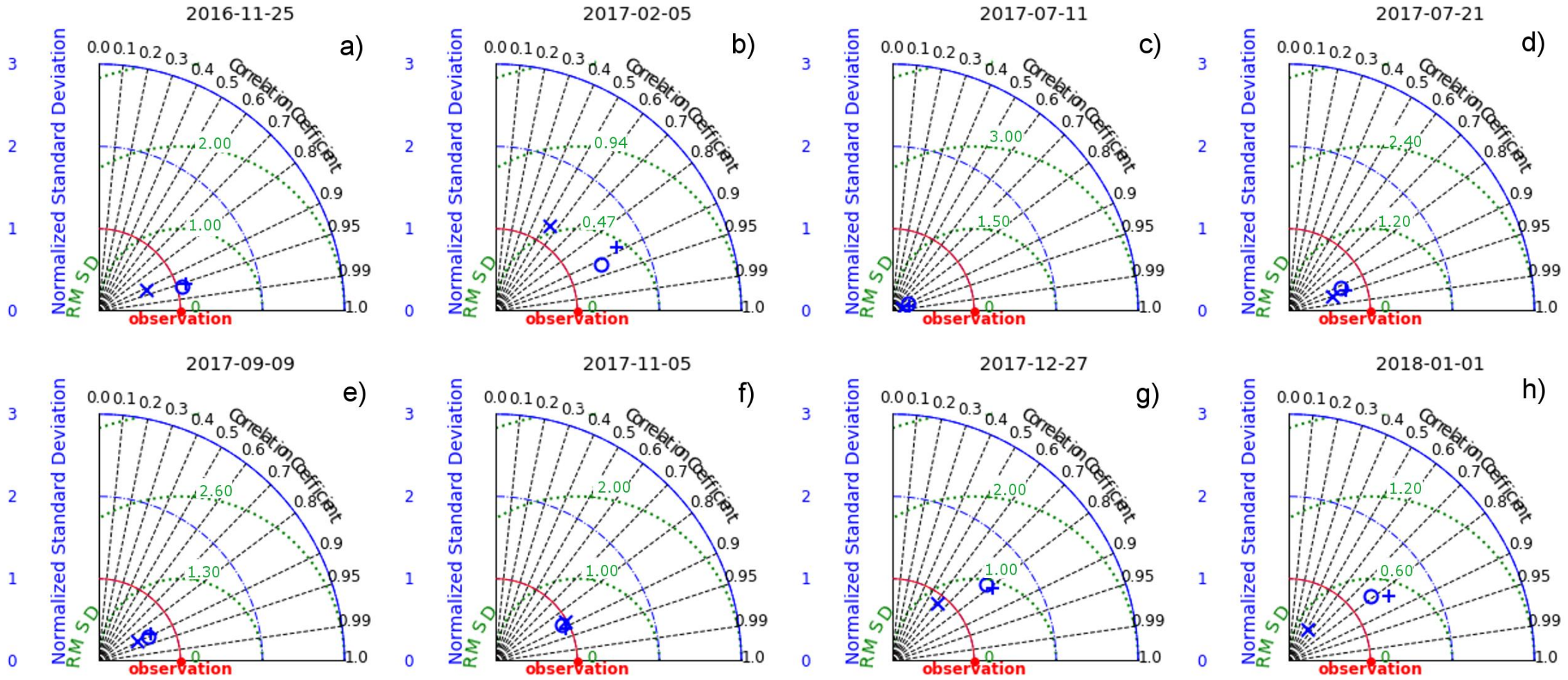
FIELD EXPERIMENT (6/6)

Taylor's diagram of the SRS 10-min rainfall intensity vs. reference measurements



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FUTURE DEVELOPMENTS

- **SRS** microwave satellite link technique can be used to provide real-time information on the rainfall rate spatially averaged along the rainy portion of the link path.

- The level of the melting layer that must be assessed in order to implement a network of **SRS** sensors for real-time monitoring of precipitation fields.

- To investigate the effect of the type of precipitation and particle size distribution by means of field observations made by disdrometers.

- To consider a larger network of microwave links and to use weather RADAR measurements to test advanced rainfall map reconstruction techniques, such as tomography (D'Amico et al., 2016) or ordinary kriging (Overeem et al. 2013).

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THANK YOU FOR YOUR KIND ATTENTION !

Matteo Colli
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