Comparisons of precipitation measurement methods in landslide instrumentation in the Alpes-Maritimes (France)

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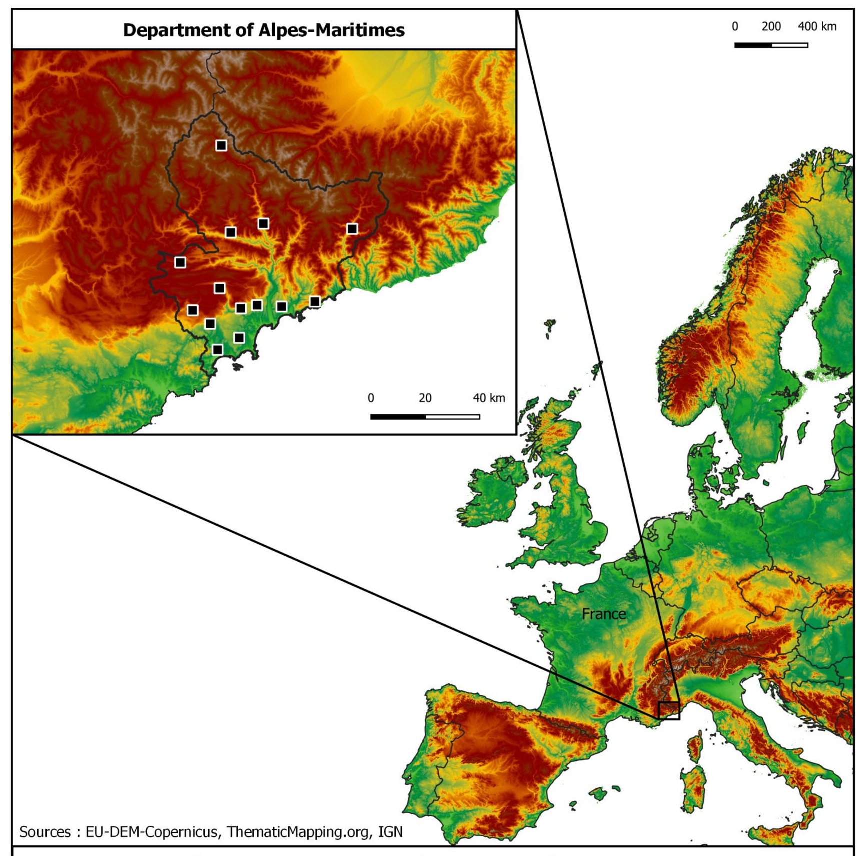
1 – Current instrumentation of the Géoazur laboratory

The Géoazur laboratory, as part of its scientific objectives aiming at monitoring landslides, is setting up natural observatories mostly located in the Alpes-Maritimes department (France). Those natural demonstrators allow the implementation of multi-parameter measurements on landslide-prone slopes. Since precipitation is one of the main factors triggering gravitational instability, we initiated a reflection within the laboratory on the spatial variability of precipitation and on the ways of measuring this rainfall within the observatories set up.

The Alpes-Maritimes department, due to its very contrasted relief (see location figure on the right), is particularly exposed to high spatial variability of precipitation (blocking phenomenon). Due to its location, close to the Mediterranean Sea, convections are reinforced in autumn, with convective rainfall of short duration and high intensity.
These different variabilities create additional challenges precipitation measurement.



Location of measurement sites of the Géoazur laboratory

Water is the main factor triggering gravitational instability, through its action on surface water tables. Understanding the role of precipitation in the loading of surface aquifers can thus improve the overall understanding of the gravitational objects studied.

Since 2006, various landslides have been instrumented with multiple sensors, including weather stations, to record precipitation. On the pictures at the left: on the top left, the Clapière slide (65 millions m^3); on the top right, the "Ruby" site for monitoring rocky scales threatening a road; on the bottom right, the Clape slide threatening the obstruction of a river, and finally on the bottom left a more recent installation in the Bendola valley on the Italian border.

Therefore, the installation sites are often hostile areas, subject to various constraints and sometimes on north slopes, leading to high energy dependencies. These fields are always difficult to access, making it uneasy to carry out any maintenance work. Until today, rain gauges used by the laboratory are all tipping bucket systems (see pictures at the right).
These rain gauges are among the most widespread and allow a reliable measurement (uncertainty margin of 10%). However, due to their simplistic operation, they require special care to avoid clogging the cone with insect, leaves or bird droppings, for example.


« *Davis Instruments* » tipping bucket rain gauge

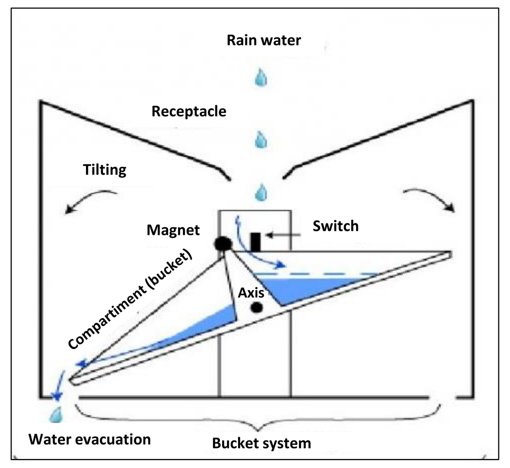


Diagram of tipping bucket rain gauge, modified from Meteo-France

In our case, the main disadvantage of using this type of rain gauge is the difficulty of performing regular maintenance. This lack of maintenance **results in a 100% error** from time to time when the rain gauge funnel becomes clogged.
Calibrating this rain gauge is also difficult to do in the field, and **drift after installation also leads to a measurement error**, which may increase over time.
However, this system is also very unlikely to experience electronic failures, and requires little energy, which is why it has been preferred until now.

2 – New types of sensors, interests and objectives

The objective is to try to eliminate as much as possible the risk of reaching a 100% measurement error (no precipitation measurements while it is raining) due to the obstruction of the rain gauge funnel for example.
To achieve this objective, several things are possible, such as enlarging the collection surface (of the funnel), and setting up larger grids to filter out coarse elements. This method could limit grid obstruction, but increasing the catchment area would result in a greater obstacle to airflow, and therefore more turbulence.

A second possibility is to use instruments without any mechanical elements, both for rain and wind measurements. This can reduce the need for maintenance and cleaning.
In recent years, new sensors have made this possible, such as the complete *Lufft* weather station, with a 24 GHz Doppler radar for precipitation measurement and a sonic anemometer for wind measurement (see diagram and picture at the right).
This radar technology measures the size and velocity of drops in a column of air above it, and infers a quantity and intensity of precipitation using correlation methods. The measurement of the size and speed of hydrometeors also allows us to deduce the type : rain, hail or snow.

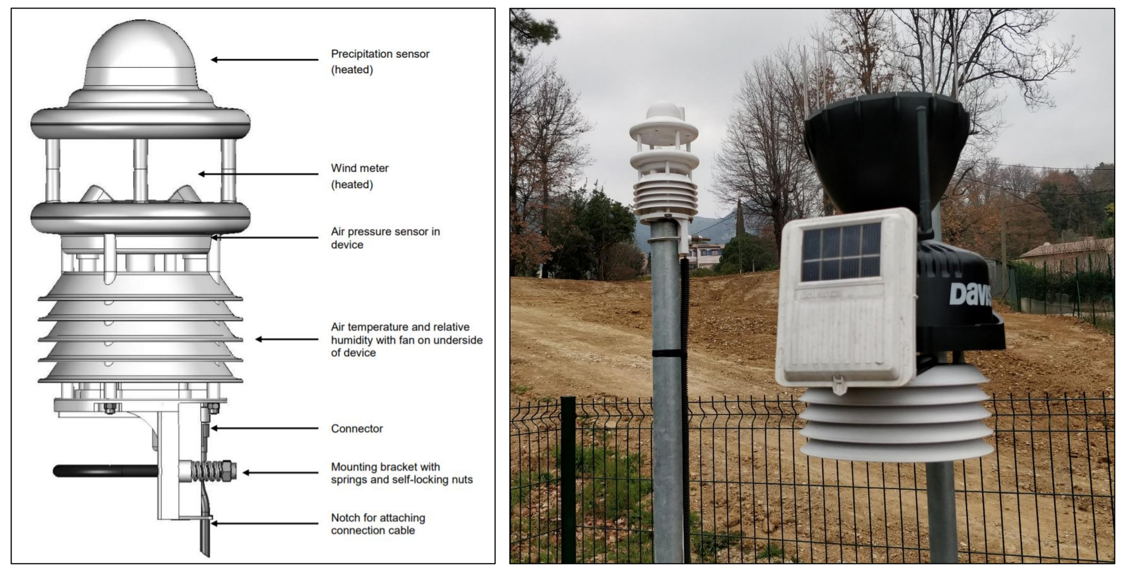
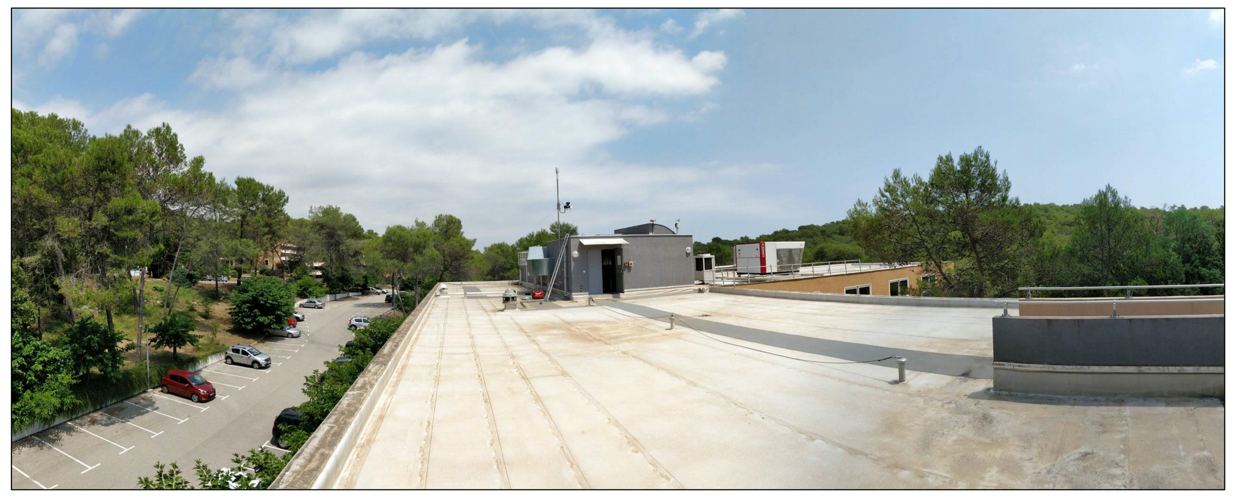
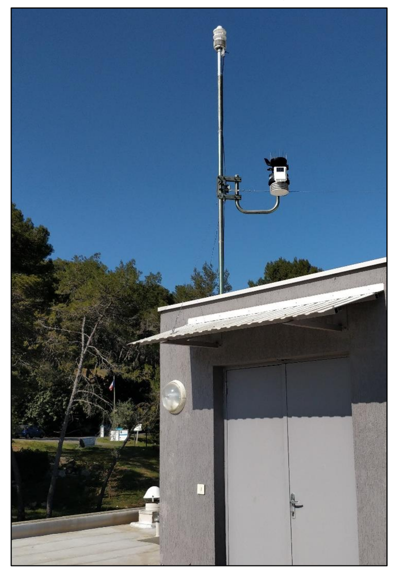


Diagram of a *Lufft WS600* weather station on the left, and picture of a Géoazur laboratory weather station installation on the *Vence* landslide « *Prat de Julian* » on the right. The diagram shows the position of the 24 GHz Doppler radar for measuring precipitation. The picture on the right shows one of the two current installations that will be used for the inter-comparison of rain gauges. In the foreground, we see a *Davis Instruments* weather station (*Vantage Pro 2* model) with a tipping bucket rain gauge. In the background, a *Lufft* weather station (model *WS700*) with a 24 GHZ Doppler radar rain gauge.

Therefore, we have started to carry out an inter-comparison between these two automatic weather stations, in order to control the quality of their measurements, and to evaluate the influence of wind and nearby obstacles in real conditions.
To achieve this, we installed the two *Davis Instruments* and *Lufft* stations (see pictures below) on the roof of the laboratory building in mid-2018, as well as a manual *SPIEA* rain gauge. On this site the three rain gauges are not at the same heights, which can lead to differences due to turbulence caused by wind and massive buildings.
More recently, we have also installed the two automatic weather stations at the *Vence* landslide site « *Prat de Julian* », but this time at the same height (see photo above), and in a more open environment.





3 – First results of inter-comparison

The results presented here are only preliminary, since for the rain gauges located on the roof of the laboratory we only collected 9 significant events with more than 30 mm of rain.
These initial results (see graph below) show a significant difference between the bucket rain gauge (*Davis Instruments VP2*) and the radar rain gauge (*Lufft WS700*). Over the first 6 events, the bucket rain gauge shows acceptable results compared to the manual rain gauge (*SPIEA*), within the range of the 10% errors recognized in the bibliography. But then, there seems to be a tendency towards underestimation, which is becoming more and more pronounced. Could this be a sign of a drift in the calibration of the buckets?
For the radar rain gauge, the first events show very varied results, with a very large overestimation compared to the manual rain gauge during the event of 11/10/2018 (event n°2). But then there seems to be a downward trend in this overestimation.

For the *Vence* landslide site (*Prat de Julian*), since the installation of the two automatic weather stations, only two significant events have been identified. The results cannot therefore be representative, but seem to show for the moment a smaller difference between the two stations, probably due to the fact that they are installed at the same height and the fact that there are fewer obstacles nearby.

This comparison will continue for at least two years at both sites, in order to cover all seasons, and the different types of rainfall events that the Alpes-Maritimes department may experience. It is also planned to test other rain gauge models in the coming months.

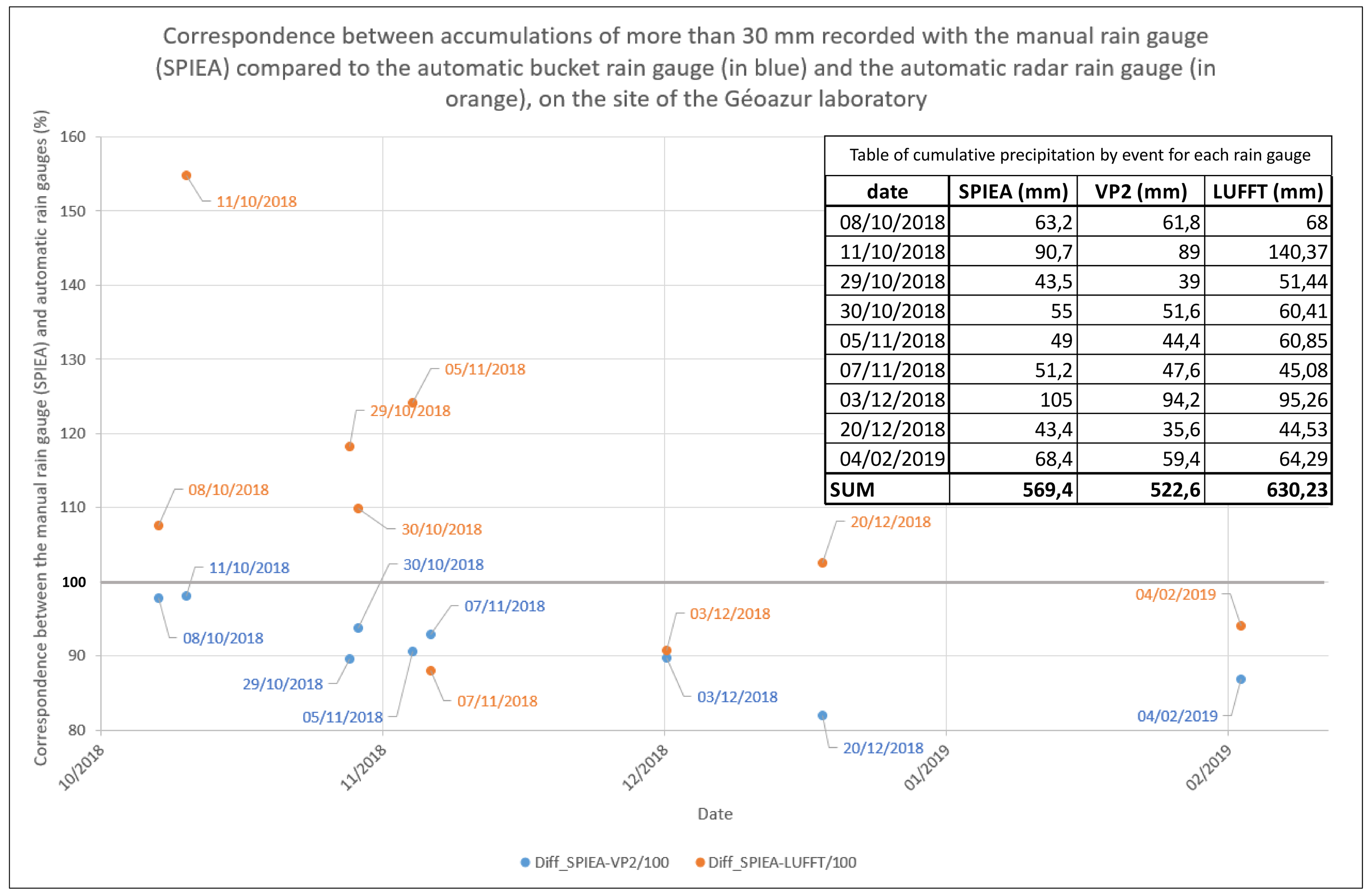
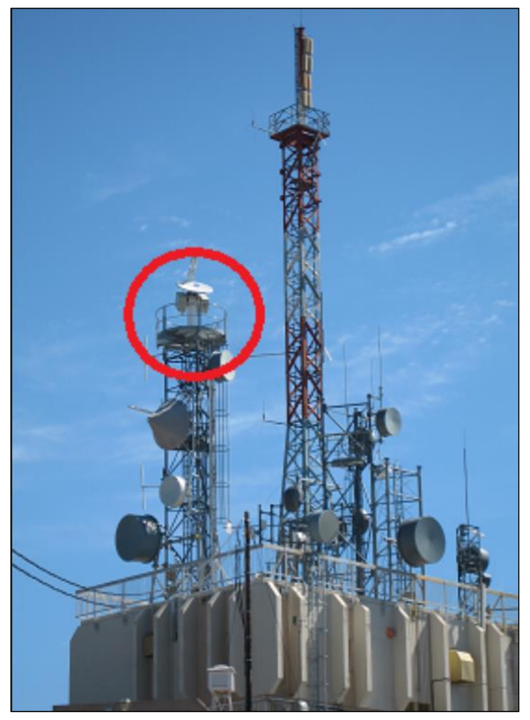


Table of cumulative precipitation by event for each rain gauge

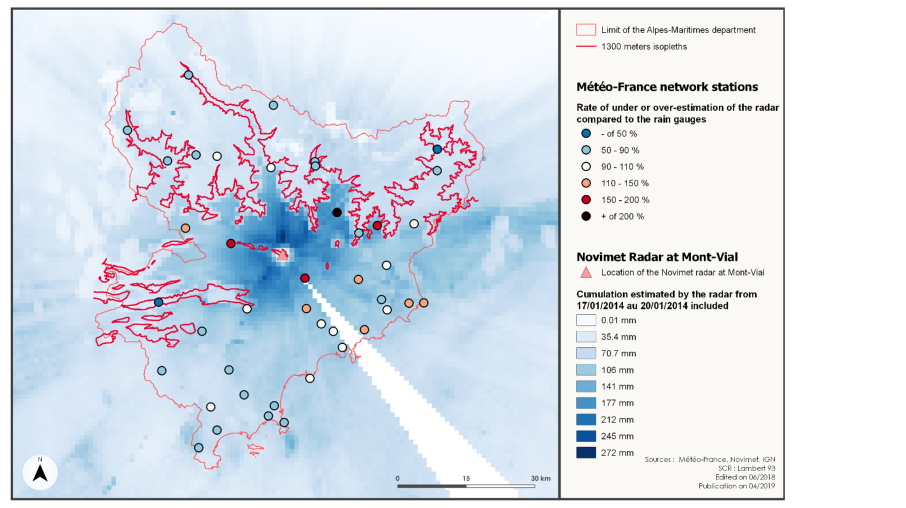
date	SPIEA (mm)	VP2 (mm)	LUFFT (mm)
08/10/2018	63,2	61,8	68
11/10/2018	90,7	89	140,37
29/10/2018	43,5	39	51,44
30/10/2018	55	51,6	60,41
05/11/2018	49	44,4	60,85
07/11/2018	51,2	47,6	45,08
03/12/2018	105	94,2	95,26
20/12/2018	43,4	35,6	44,53
04/02/2019	68,4	59,4	64,29
SUM	**569,4**	**522,6**	**630,23**

4 – Inter-comparison rain gauge *Météo-France* and *Mont-Vial* radar

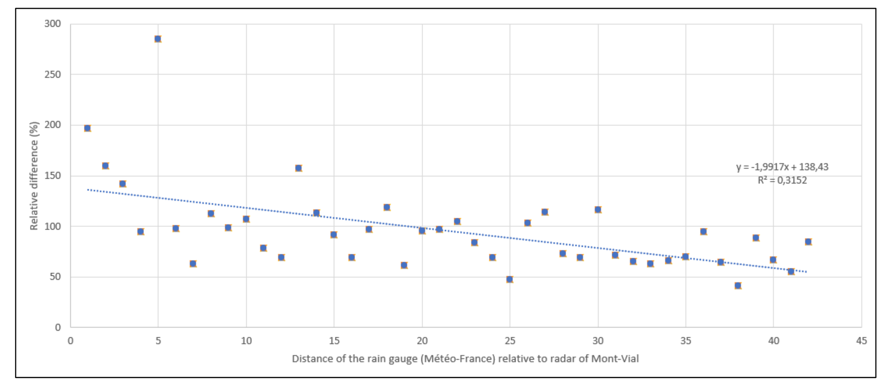
As part of a European project (AD-VITAM), we were able to carry out another type of comparison. This involves comparing scattered data (rain gauge) with spatialized data (radar) over a daily time step. For the radar data, we were able to use those produced by the X-band and polarimetric Doppler radar, operated by *Novimet* in the *Alpes-Maritimes* department (Mont-Vial - France). These spatialized data were compared with automatic rainfall data from the "*Radome*" network of the National Meteorological Institute *Météo-France*. Data from several rainfall events were acquired and compared. They highlighted the difficulty of estimating precipitation over a territory with a highly contrasted relief and intense rainfall events.


Implementation of the *Hydrix* radar (red circle) on *Mont-Vial* north of Nice (Illustration from *Novimet*)
Installed since 2007 on Mont-Vial (1150 metres above sea level)

Below, is presented the result of a comparison between the accumulation observed by the radar, and the accumulation observed by ground stations in the pixels. This map represents a rainy event from January 17, 2014 to January 21, 2014.
This event is part of the low pressure trough system in the Gulf of Lion, with a rain/snow limit between 1200 and 1500 meters. It is interesting to note the appearance of landforms in the spatialization of radar accumulation, influenced by snow.



Comparison of precipitation simulated by the *Novimet* radar (at *Mont-Vial*) with the precipitation measured by the *Météo-France* rain gauge network


Relative difference accumulative rain of radar compared to rain gauge *Météo-France*

Despite all the limitations of this method, the comparison shows on average a good correspondence between the accumulation observed by the radar in a pixel compared to the accumulation of the 42 weather stations of the *Radome* network of *Météo-France*. On average over the department, the radar underestimates by less than 5% the accumulations observed by ground-based rain gauges. Nevertheless, rain accumulation is sometimes over- or underestimated by radar. There is a slight dependence (coefficient of determination is 0.31) between the result of underestimation of the radar and the distance of the rain gauges from the radar (see graph below). Comparisons of this type are still ongoing on other types of events.