Copernicus Climate Change Service

FLAUDE PROJECT

Products (maps, graphics) on past and future climate indicators about extreme precipitation event to be visualized in FlAude demonstration case on C3S portal

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1. Introduction – Scope of the document

The FlAude C3S Use Case is intended to contribute more widely to the FORO project : Flood Observatory for Resilient Occitany, by contributing to the understanding of extreme hydrometeo phenomena and to the elaboration of methods for prevention and risk reduction, adapted to the use by local decision makers. Thus, the selection, the construction and evaluation of indicators on hydrometeorological hazards related to floods is at the heart of the approach developed in the project.

This deliverable is based on the preliminary work developed in the first report D3.1 on the hydrometeorological characterization of extreme flooding events in Aude and the comparative evaluation of C3S and Meteo-France data sets.

The construction of hydrometeorological indicators is also based on regular discussions with the project partners to develop a coherent approach to adapt the territory to flooding, combining climatic, spatial and socio-economic data on the territory. Despite the difficulties related to COVID19, two meetings were held in 2021 with potential users of the service (28/01/2021 and 18/05/2021) with exchanges on their expectations regarding past and future hydrometeorological indicators.

The indicators can take the form of a map or a graph and are associated with messages on the knowledge of extreme flooding events in the territory and their evolution.

2. Data selection

The data used for the construction of the hydrometeorological indicators are those of report 3.1 with the correspondences established between C3S and Météo-France data mainly for hourly and daily extreme precipitation, and secondly soil moisture and flow, which are not readily available to date in future climate. The period considered, past or future, implies the selection of different data.

For the observation of climate change, we recall that we consider :

- For hourly precipitation, COMEPHORE data from Météo-France available since 1997 or ERA5 Land from C3S available since 1979.
- For daily precipitation, we considered PRESCILIA data starting in 1958 or UERRA data starting in 1961.
- For soil moisture, data coming from SIM2 reanalysis of Météo-France starting in 1958 or those of the 3 products ERA5 Land, UERRA or EFAS of comparable quality.
- For river discharges, the local observations or the EFAS products, available since 1991.

For future climate indicators, it is essential to work with the highest spatial resolution data and we therefore use the Eurocordex data available on C3S or the DRIAS-2020 selection established over France by Météo-France.

3. Event selection and climatological classification

The approach to the selection of extreme events was presented in report 3.1 and aimed at selecting a reduced number of events rainfall with a return period of at least ten years triggering the natural disaster compensation procedure in France.

The map below is the spatialization of the 10 years return periods of rainfall on 48 hours of amount precipitation based on the SHYREG method[1] developed by INRAE and Météo-France, used for the operational procedures.

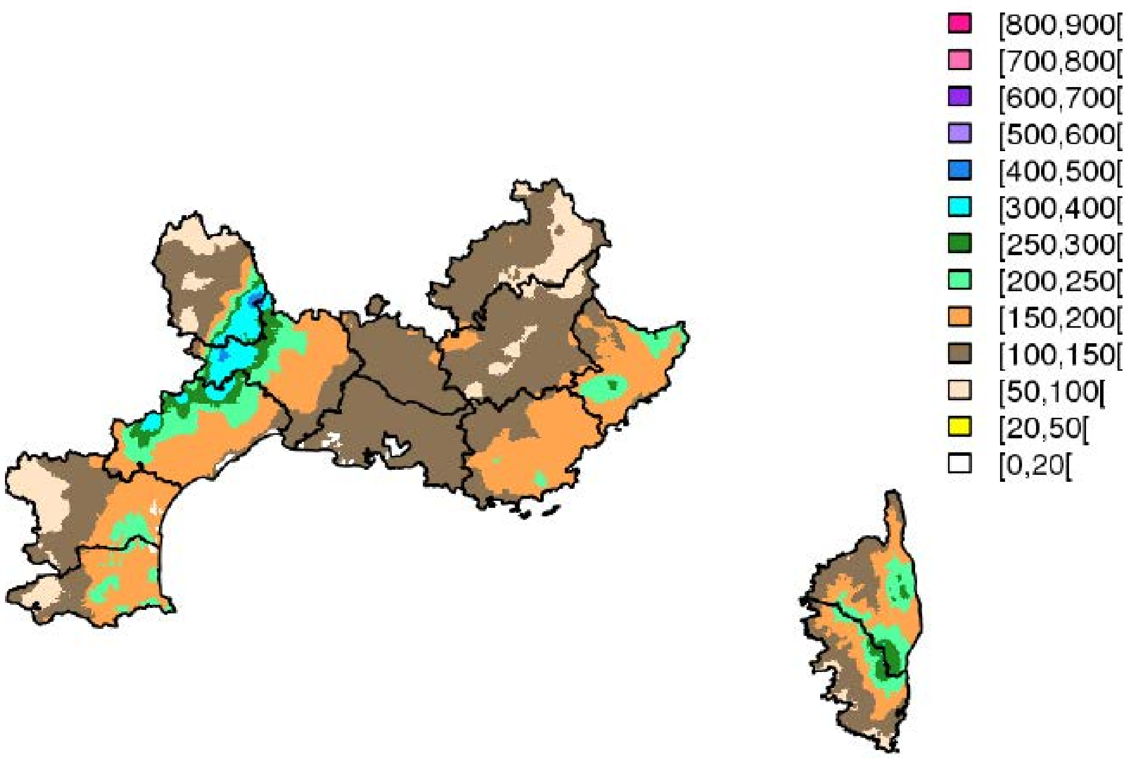

***Figure 1** : 10 years return period of 48h amount of precipitation on the French Mediterranean regions from the SHYREG method.*

In Figure 1, four different zones appear in the department of Aude with values generally between 100 and 200 mm, slightly less than 100 mm in the west and more than 200 mm in the Corbières relief zone along the coast. The threshold of 200 mm, which maximizes the local decadal return period, allows us to retain 20 events over the period 1997-2020, i.e. approximately one event per year on the scale of the territory. The values of 100 mm which minimizes the 10 years return period will also be considered to define the spatial extension of a specific event. The list of the 20 events is discussed in the next section.

The approach followed can be applied to another territory but may lead to a different choice of event selection threshold.

[1] SHYREG : regionalization of the SHYPRE method based on a rainfall stochastic generator

The SHYREG 10 years return periods on time steps of one to several hours will be used in FORO as a climatological indicator of the intensity of extreme rainfall to compare different basins of the department of Aude or to qualify particular events.

For example, the Figure 2 shows the 10 years return period for 1h amount of precipitation in the department of Aude. The four areas repartition is slightly different than for 48h with a strong contrast from East to West on the territory with values between less than 30 mm to more than 50 mm.

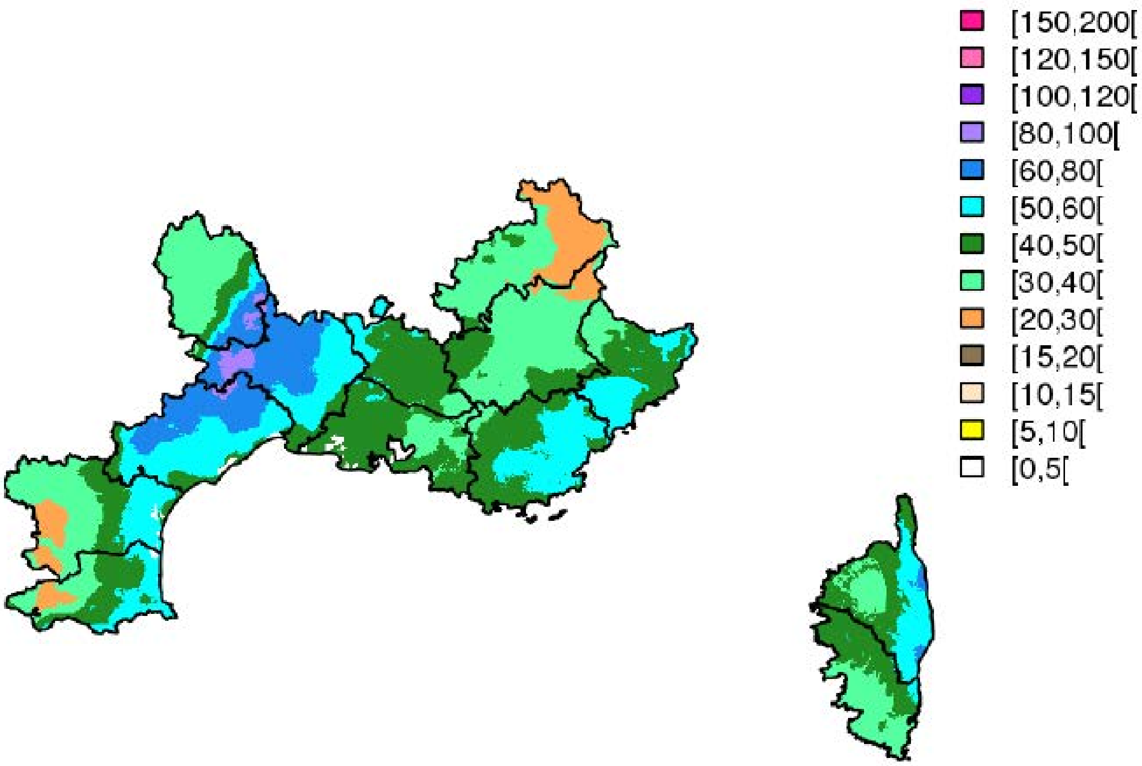

Figure 2 : *10 years return period of 1 h amount of precipitation on the French Mediterranean region from the SHYREG method.*

4. Characterization of the extreme events

Each of the 20 events selected on Aude since 1997 (threshold 200 mm in 48h with COMEPHORE data) were analysed according to their characteristics for flood generation.

The criteria taken into account are at the 1km resolution

- global data on the event: maximum amount of rainfall in 48 hours, the surface area (km²) of the event above the 200 mm threshold and the total volume of rainfall on this surface area.
- maximum of rainfall intensity on the several time steps : 1h, 3h, 6h, 12h and 24h.

The table 1 below shows the values of the extremes events criteria for each event. The results are classified according to the volume of precipitation.

Date	1h max	3h max	6h max	12h max	24h max	48h max	surface	volume
19991112	106,5	227,5	354,4	482,9	563,2	621,8	2616	893761,3
20101010	38,7	71,8	102,8	154	249,6	317,7	1231	288597,7
20051113	47,9	94,5	135,9	192,7	255,5	300,2	830	179991,8
20141128	96,8	139,5	217,7	269,8	275,8	318,7	744	175055,6
20181014	66,7	151	262,9	319,8	322,7	322,7	567	139916,9
20111027	58	124,9	132,2	193,2	281	339,4	266	66792,7
20130305	44,9	91,3	142,7	187,1	269	349,6	248	57794,8
20110314	37	48,6	74,3	117,1	185,5	295,2	74	18755,5
20031115	131,1	203,2	255,7	267,6	267,6	267,6	35	7712,1
19970810	137,6	257,5	271,6	280,9	294,7	294,7	28	6356,9
20170213	35,9	61,5	99,2	160,4	215,6	230,7	26	5469,9
20141124	85,9	169	210,5	235,3	242,2	243,4	23	4999,2
20181008	71,6	112,8	121,6	141,6	189,6	228,6	20	4301,8
20000610	17,4	38,4	63,6	97,9	188	246,9	13	2849,4
20081226	18,9	38,5	59,6	113,1	162,5	214,8	8	1657
20050905	113,2	150,8	166,1	174	181,1	207,4	4	817,2
20060128	27,4	46,4	64,7	120,2	182,1	204,4	3	608,3
20051013	35,6	55,1	81,8	109,7	180,2	201,7	1	201,7
20050207	24,3	49	60,6	89,1	121,6	197,9	0	0

20120520	18,9	30	51,1	96,1	141,8	181,2	0	0

***Table 1** : Characterization of past extreme events in the department of Aude in terms of volume, surface, maximum amount of precipitation and intensity maximum in 1h to 12h. The surface and the volume are not calculated for the event with a maximum amount lower than 200 mm.*

We note that the volume and the surface area allow a better distinction to be made between major events than the cumulative rainfall in 48 hours, for which many events have almost identical values. These data of volume and surface have also been considered in other articles on extreme precipitation events (Ribes *et al*, 2018).

A classification of the 20 events was defined with the users according to four criteria explaining the damage caused by the floods (volume, surface, total accumulation and max 3h intensity) and a weight according to a tercile distribution of the different criteria for our 20 events. For each criterion, events with values in the top tercile are assigned a value of 3, those in the middle tercile a value of 2 and those in the bottom tercile a value of 1. The summary value is obtained by multiplying the 4 values. Four events obtain the maximum value (81) and can be considered as the major events on the territory : November 1999, October 2011, November 2014, October 2018.

date	**surf_weight**	**vol_weight**	**cum_weight**	**int_weight**	**Summary**
19991112	3	3	3	3	81
20111027	3	3	3	3	81
20141128	3	3	3	3	81
20181014	3	3	3	3	81
20051113	3	3	3	2	54
20101010	3	3	3	2	54
20130305	3	3	3	2	54
19970810	2	2	2	3	24
20031115	2	2	2	3	24
20141124	2	2	2	3	24
20170213	2	2	2	2	16

20181008	2	2	2	2	16
20000610	2	2	2	1	8
20110314	2	2	2	1	8
20050905	1	1	1	3	3
20051013	1	1	1	2	2
20050207	1	1	1	1	1
20060128	1	1	1	1	1
20081226	1	1	1	1	1
20120520	1	1	1	1	1

Table 2 : *Ranking of past extreme events in the department of Aude with a summary value taking into account the volume, surface, maximum amount of precipitation and maximum intensity in 3h.*

5. Maps on the extreme events

For each event, maps have been produced and get available to the FORO portal according to two representations :

- the hourly amount of precipitation during the event aiming to identify the chronology of the event,
- the summary criteria defined in the previous section. See below the maps for the event of 14th October 2018 (one of the 4 major events identified on the territory) with the maximum intensity in 1h, 3h, 6h, 12h, 24h and 48h. Here, the data used come from COMEPHORE dataset but the same representation can be done with ERA5 LAND.

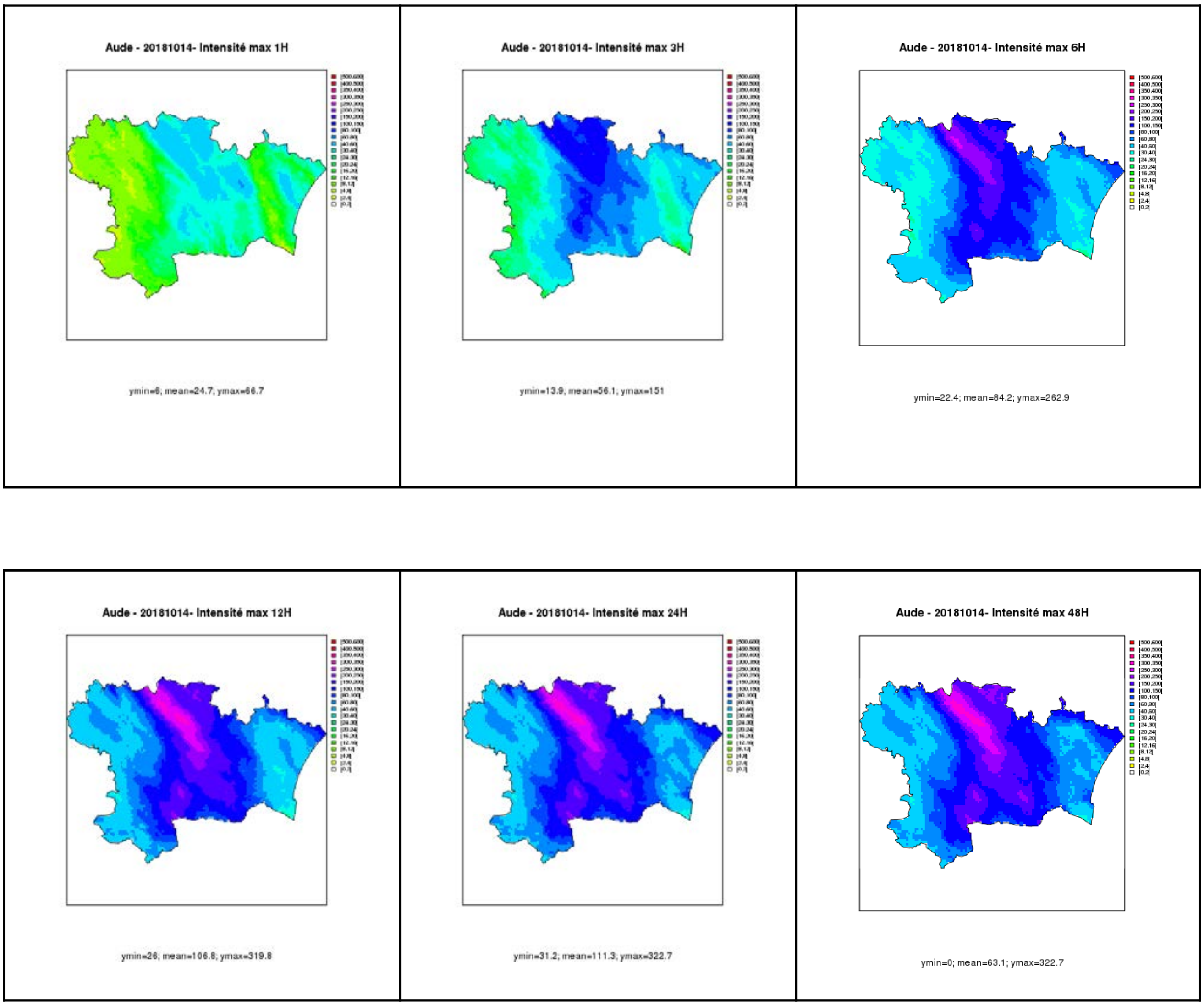

Figure 3 *: Summary maps on the event of 14th October 2018 in terms of maximum intensity in 1h, 3h, 6h, 12h and 24h*

6. Graphics of the extreme events

As the previous maps, summary graphics have been built to compare all events together.

- A first kind of representation (Figure 4) is based on bubble graphs as used on heat waves for example by Ouzeau et al, 2016
- A second kind of representation (Figure 5a et 5b) is based on bar graphs with for each event the maximum intensity in 1 to 48h, respectively with comephore and Eraland dataset over the department of Aude.

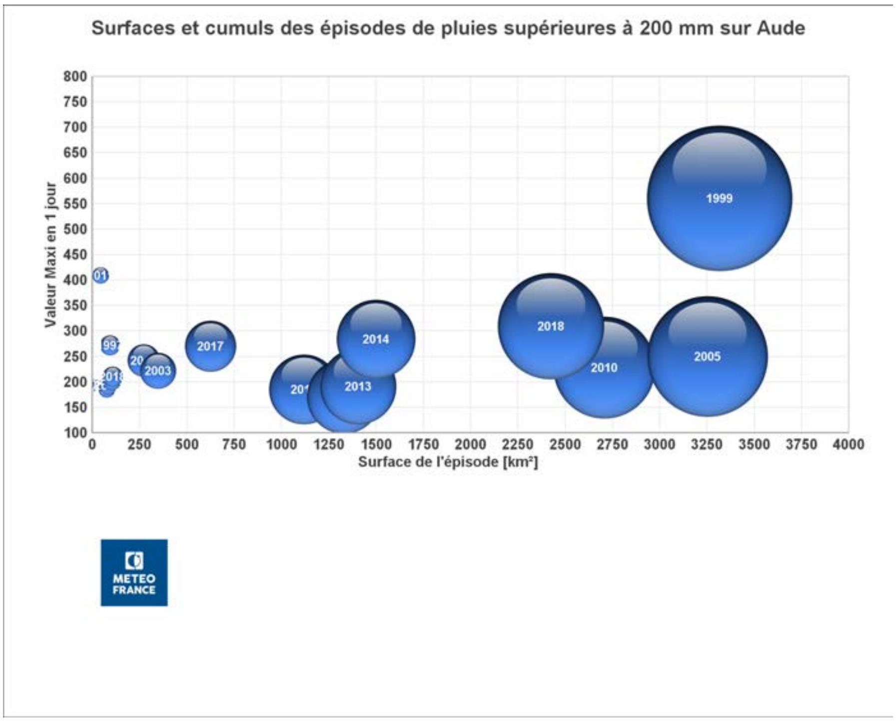

Figure 4 : *Bubble representation of the precipitation extreme events in the department of Aude in terms of surface (X axis), amount of precipitation (Y axis) and volume (size of the bubble). The year of each event is indicated on the bubble.*

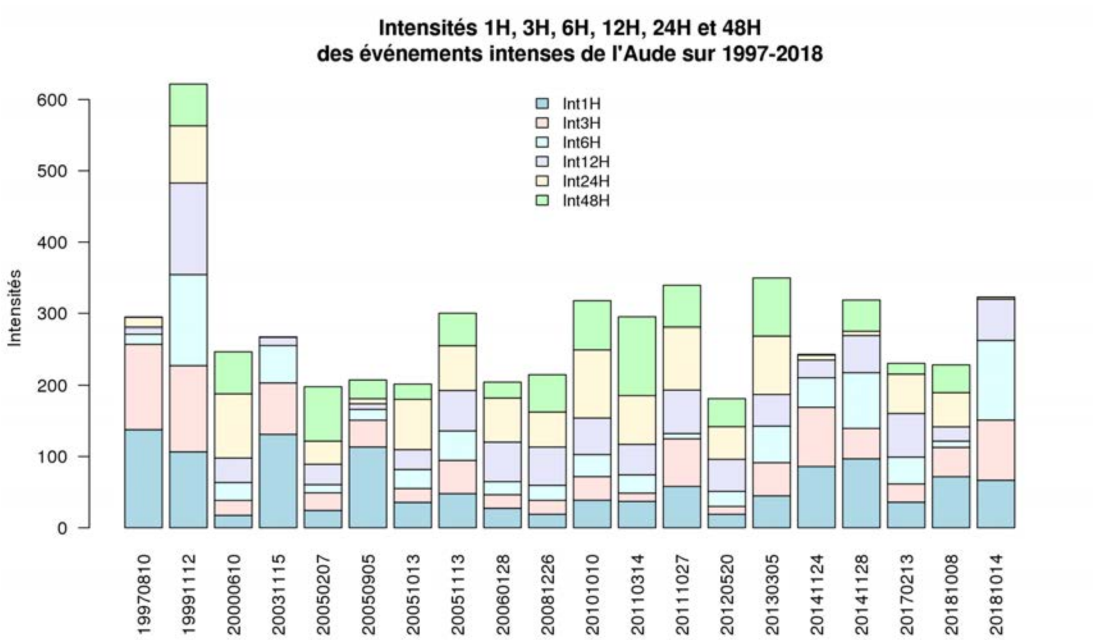

Figure 5a : *Bar graph of the precipitation extreme events in the department of Aude in terms of maximum intensity in 1 to 48h (source COMEPHORE)*

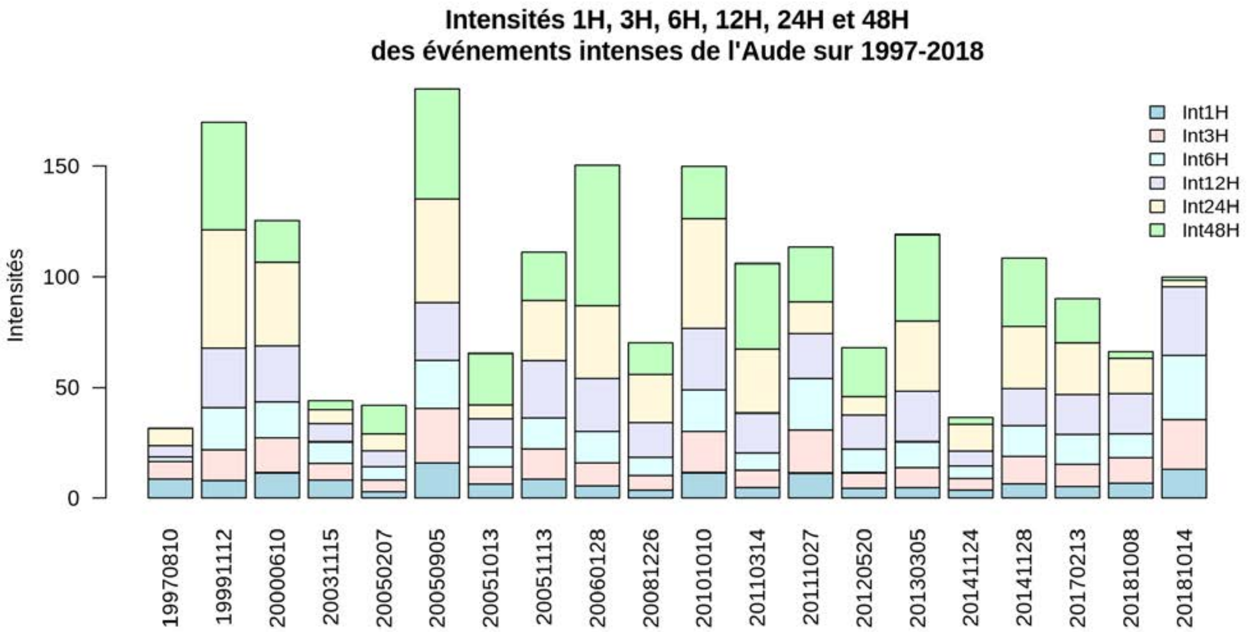

Figure 5b : *Bar graph of the precipitation extreme events in the department of Aude in terms of maximum intensity in 1 to 48h (source ERA5land)*

7. Soil moisture indicators

The soil moisture used in our indicators comes from SIM2 reanalysis at 8 km resolution but ERA5Land, UERRA or CEMS EFAS data can also be considered.

To better represent the soil moisture as a normative value, an index is calculated the Soil Wetness Index (SWI) defined by

$$SWI = (W - W_{wilt}) / (W_{fc} - W_{wilt})$$

where W is the integrated soil water content, W_{wilt} is the water content at the wilting point and W_{fc} is the soil water content at the field capacity.

The SWI is a good predictor of the runoff factor of the precipitation and can be represented in terms of maps (Figure 6) or in terms of graphs (Figure 7). The soil moisture is wetter in 2018. Soil moisture is much wetter in 2018 than in 2014 because an intense rainfall event occurred 8 days before and explains stronger hydrological responses for equivalent rainfall amounts.

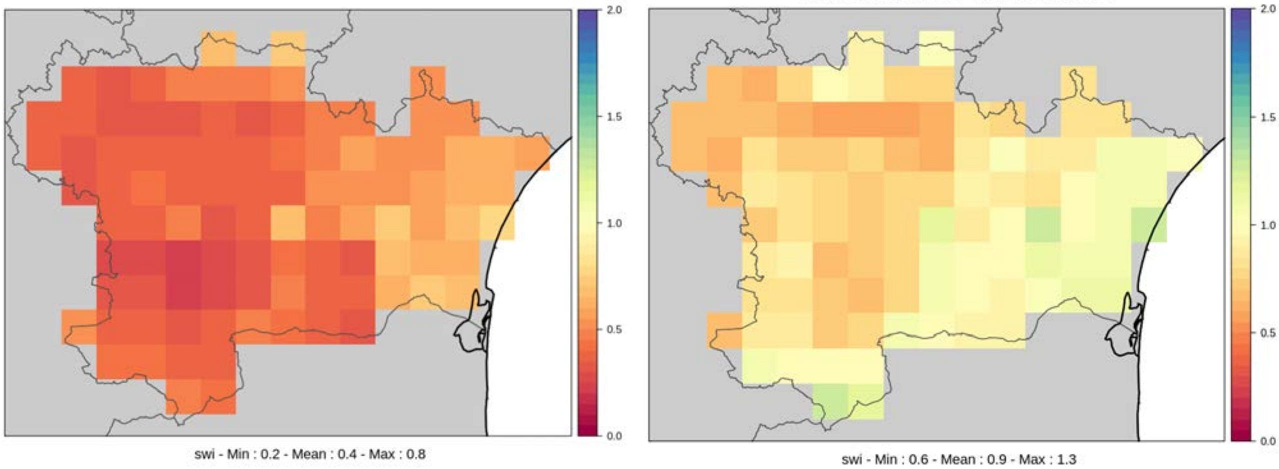

***Figure 6** : Maps of the Soil Wetness Index (SWI) on the department of Aude for the event of November 2014 or October 2018.*

The representation in the form of a graph on the scale of the Aude department and compared with the SWI climatology over the period 1981-2010 makes it possible to characterise the temporal evolution of soil moisture over several weeks and to identify a possible context of drought prior to the event or, on the contrary, a succession of events of high moisture.

In Figure 7 for the 2014 event, the situation evolved in a few days from a dry record to a wet record of soil moisture, which is a classic of the Mediterranean climate.

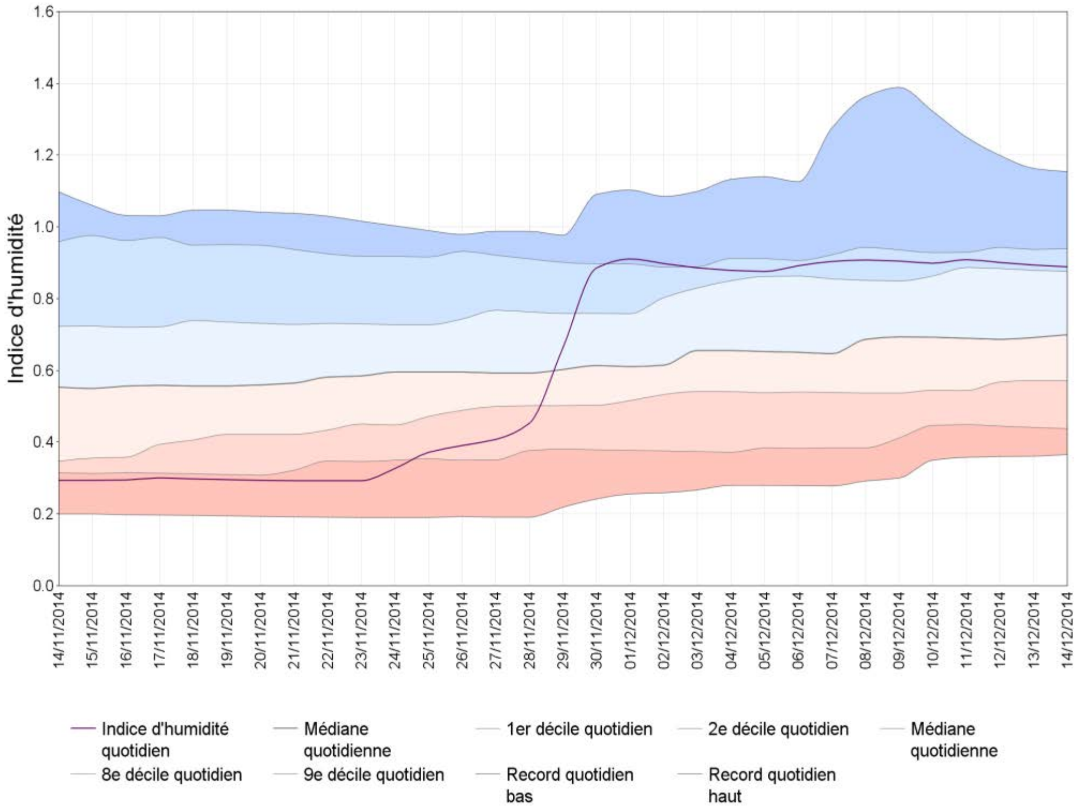

Figure 7 *: Evolution of the Soil Wetness Index (SWI) on the department of Aude for the event of November 2014 (purple line) in comparison with the 1981-2010 climatology in terms of percentile 1 to 9 (background color : blue color for wet percentile, red for dry ones).*

8. Climate futur indicators

In future climate, the analysis of the evolution of extreme rainfall is based on the DRIAS-2020 dataset (a subset of the C3S EuroCordex dataset that has benefited from some post-processing: see report D3.2) available at 8 km resolution over the Aude.
Three climate scenarios are considered (RCP2.6=low emission, RCP4.5=moderate emission and RCP8.5=high emission) as well as 3 time horizons (H1=near, H2=medium, H3=far).
From 8 to 12 simulations are available according to the climate scenarios and several climate indicators have been considered, in particular the total annual precipitation (PRCtot), the daily maximum annual rainfall encountered in 1% of cases (P99), the maximum annual 1-day rainfall (Rx1d). Distribution parameters were calculated from our multi-model set: P5, P50, P95 (P5, respectively P50, P95) is the lowest value observed in 5% (50%, 95%) of cases
The indicators have been calculated as a deviation from the average on the reference period 1976-2005 and aggregated at the regional scale for a more robust trend signal. Several kinds of representations have been produced for the FORO portal: temporal graphs, maps, tables.

a. Temporal graphs

The indicators defined above, have been calculated on the three climate scenarios and the set of climate simulations (8 to 12 simulations). They are represented in the form of temporal graphs. Figure 8 shows the results for the RCP 4.5 scenario and the four seasons.

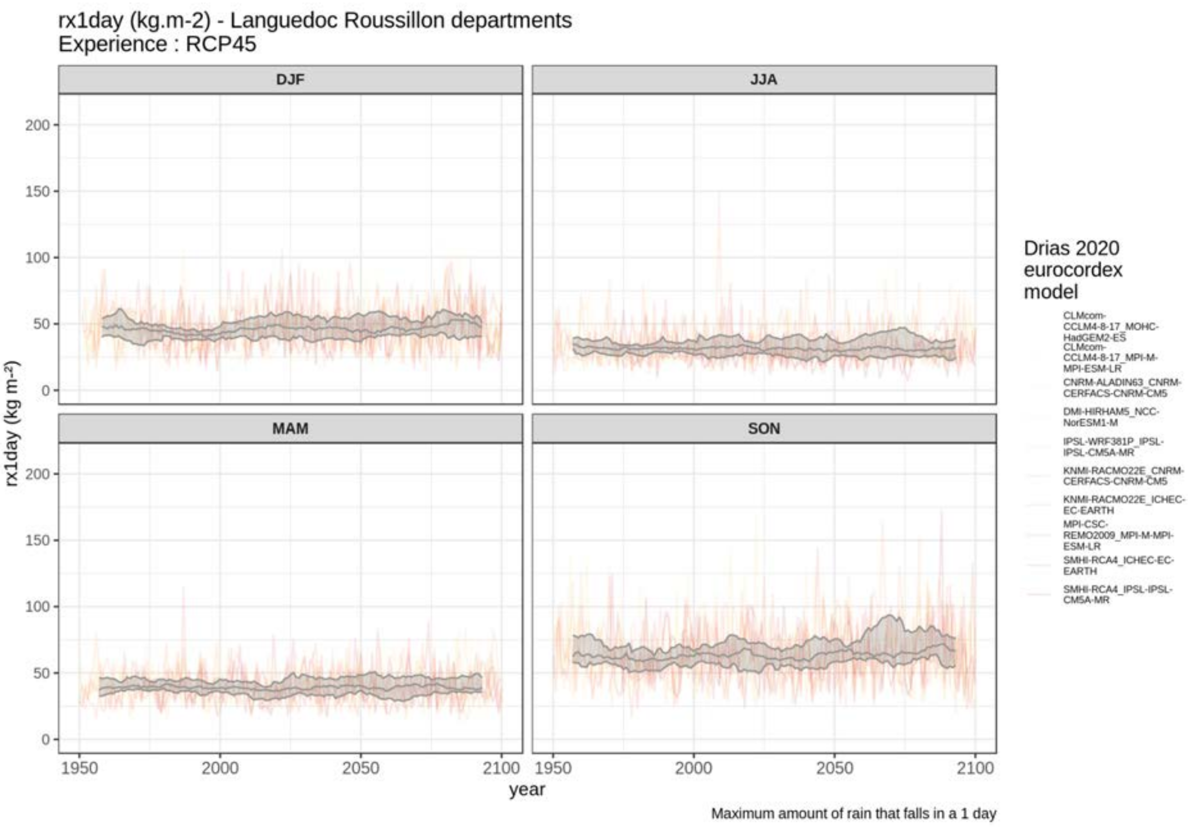

Figure 8 *: Seasonal evolution of the Rx1d indicator (max annual rainfall in 1 day), from 1950 to 2100 with the DRIAS-2020 dataset under RCP4.5 (grey line for percentile 5,50,95).*

b. Model and multi-model map representations

The maps produced concern the three scenarios applied respectively to a particular simulation or a parameter of the distribution of our multi model sets with the percentile 5, 50 and 95.
Figure 9 shows an example for RCP4.5 with the three time horizons and the percentiles 5 to 95.

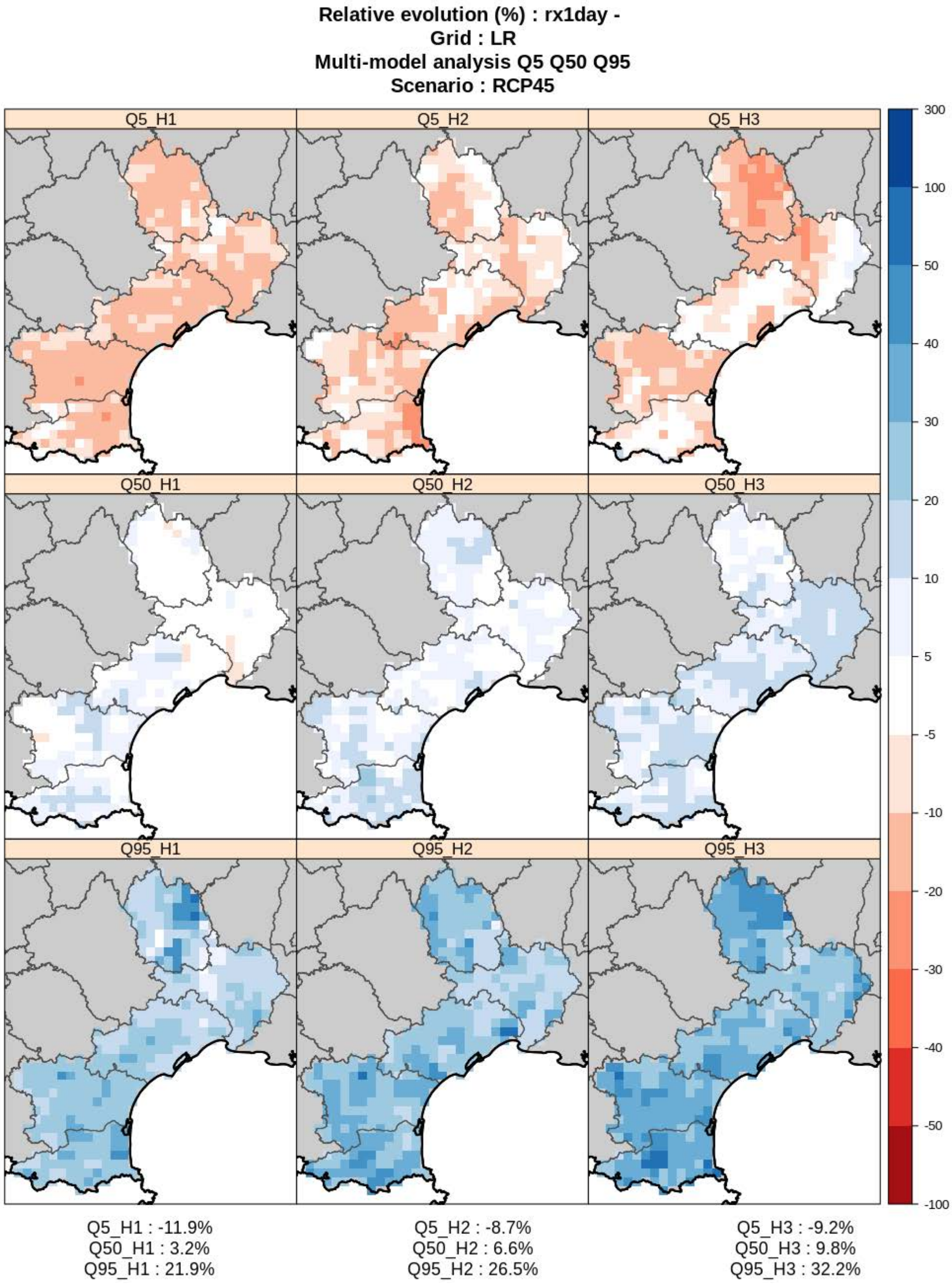

***Figure 9** : Multi model representation of the evolution of Rx1d indicator under RCP4.5 with three time horizons and three percentiles (P5, 50, 95)*

c. Summary tables

Summary tables were produced with the evolution of the indicators for each simulation for the three RCP scenarios, the four seasons and the three time horizons. This representation mode (see Figure 10) allows to visually identify the dispersion (or coherence) of the evolution of the indicator according to the scenarios, the seasons and the time horizons.

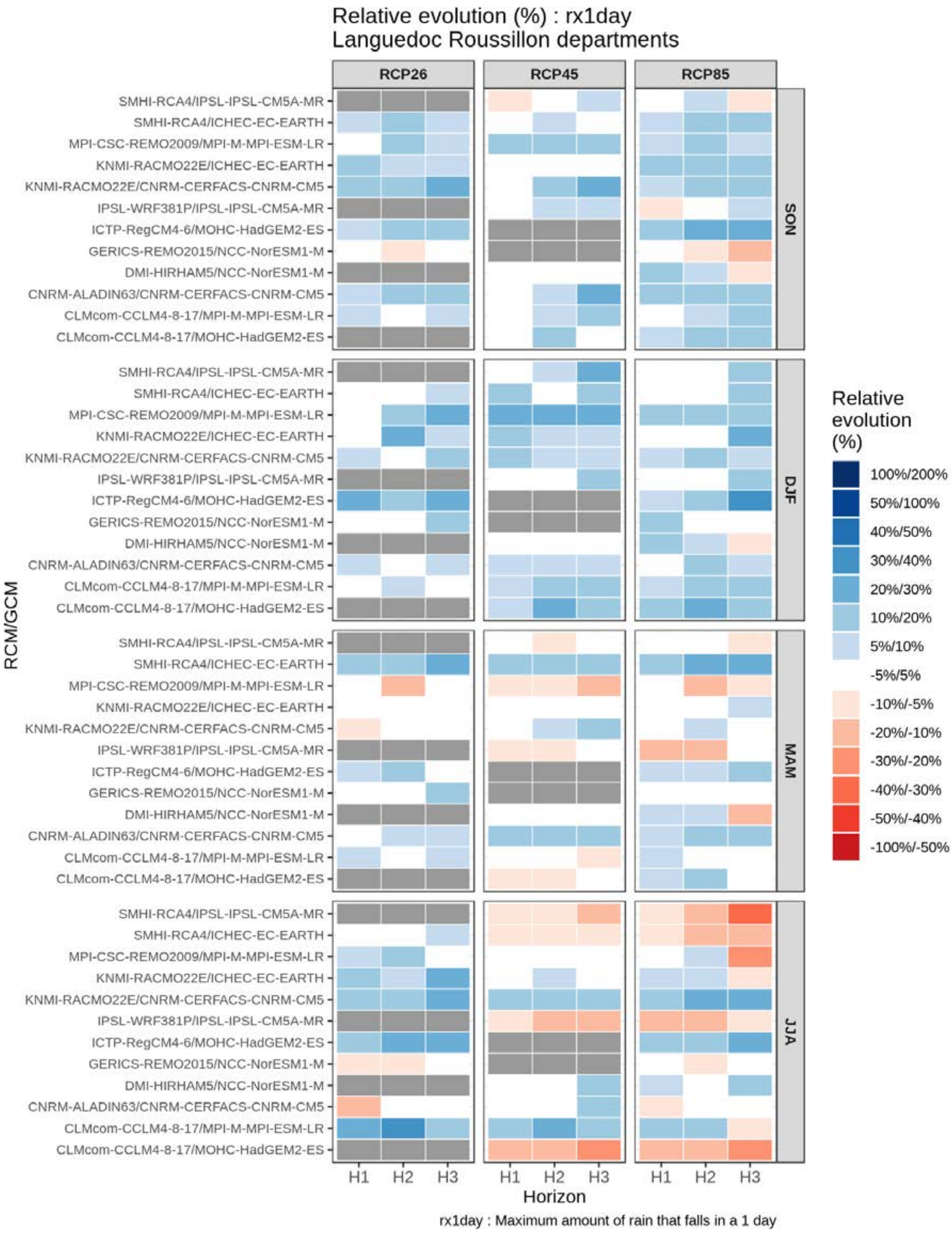

***Figure 10** : Table representation of the seasonal evolution of Rx1d indicator with three RCP and three time horizons : the color of the box in the table indicates the value of the change (red for decrease, blue for increase).*

9. Conclusion

All the maps and graphs presented in this report will be soon available on the FORO portal to be used for the adaptation approach on the flood risk in the department of Aude. The work has been mainly done with Meteo-France datasets but the same representation can be done with the C3S datasets.
All the software tools developed are based on R library and will be available on request.

10. References

Ribes A., Thao S., Vautard R., Dubuisson B., Somot S., Colin J., Planton S., Soubeyroux J.-M., 2018. Observed increase of extreme daily rainfall in the French Mediterranean, Climate Dynamics, DOI : 10.1007/s00382-018-4179-2 CLDY-D-17-00226.

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