CRP F31006 Country Summary

Country: FRANCE
Project title: Isotope Variability of Rain Assessing Climate Change Impacts over France
CSI: Elisabeth Gibert-Brunet
Attending the 2nd RCM: Elisabeth Gibert-Brunet
Research Group: HYDRO3G-Team of the UMR8148-GEOPS "Geosciences Paris-Sud"
Affiliation: CNRS-University Paris-Saclay, Orsay, France
Emails: elisabeth.gibert@universite-paris-saclay.fr / obsidienne505@gmail.com

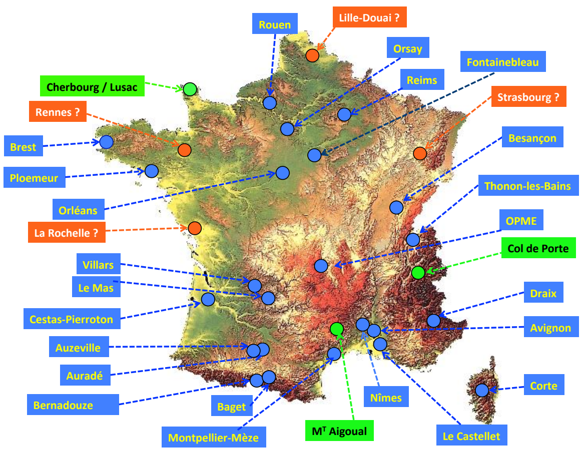
Oral presentation title: The RENOIR Network of Isotopic Signatures of Precipitations over France: development of Metropolitan and Overseas Stations. Comparative results.

1. Introduction and objectives

As presented during the first RCM of the AIEA CRP F31006 in December 2019, the French Observatory RENOIR (National Observation Service or SNO RENOIR labeled by the *Centre national de la Recherche Scientifique*) is a perennial structure of the isotopic composition of precipitations (δ^2H and δ^{18}O). It has been built up in France to (i) federate, (ii) normalize, (iii) support and (iv) share essential data that will be used by a large scientific community.
The RENOIR Network has been built up to share practices and methods at all stations (same sampling and analysis protocols), to support long-term time-series of precipitation isotopic composition, to improve our capabilities to better understand isotopic variations of precipitations over the French territory, in relation with climatic zones such as Atlantic-, Mediterranean- and mountain types and in relation with extremes events such as flood/dryness.
As a reminder, spatial and temporal variability of δ^{18}O and δ^2H in precipitation is related to (i) large-scale dynamics and atmospheric conditions (so-called "climatic conditions"), either via air mass trajectories, temperatures, precipitation amounts, or relative humidity conditions [Craig, 1961; Dansgaard, 1964; Clark and Fritz, 1997] and (ii) local- to regional-scale climatic conditions (continental moisture sources, geographic conditions, etc.). In France like elsewhere in Western Europe, climate variability is linked to depressions alternating with strong (or weak) anticyclones, both bringing westerly flows and mainly controlled by the North Atlantic Oscillation (NAO). Although several "weather regimes" can be distinguished in winter (NAO-, Atlantic Ridge, Blocking, NAO+) and summer (NAO-, Atlantic Ridge, Blocking, Atlantic Low), fall and spring regimes are considered as transition periods when it is extremely difficult to define a precise origin of air masses [Ringard et al., 2018].

2. Evolution of the RENOIR network

The RENOIR network began in February 2019 with 16 sampling stations related to 14 research laboratories. The RENOIR Network has since grown to include today over 21 laboratories that manage 31 sampling stations on the French national territory and over-seas islands. In the next two years to come, we expect to set up 4 additionnal stations in the zones that are not already well covered in mainland France (East, North, Middle Brittany and along the Atlantic coast; in red on the the figure 1) as well as and its overseas territories (New Caledonia in the red circle on the Figure 1).



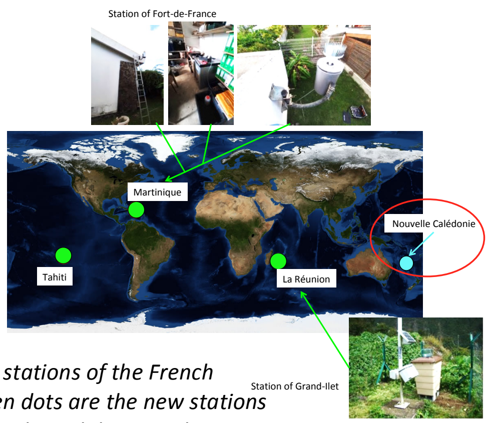


Figure 1: Map of sampling stations of the French RENOIR Network. The green dots are the new stations that will be set up in 2021. The red dots are the station locations that are planning to set up in 2022.

In parallel to its development, the RENOIR Network is engaged in the national evolution of observation services: all the French networks providing measurements and monitoring of environmental parameters documenting the "Critical Zone" [Gaillardet et al, 2018] will eventually be gathered in the eLTER-France OZCAR research infrastructure. This evolution is linked to the willingness of French research authorities to group together observation services (and thus observation sites) into large national research infrastructures that can be read by the research communities but also by European research authorities.

Beyond the focus on the origin and evolution of air masses giving rise to precipitations for the production of "local- to regional-" model outputs of isotopes in precipitation, the objectives of our project within the IAEA-CRP F31006 aim to decipher both the respective impacts of anthropogenic- and/or climatic-induced influences on the precipitation regimes, and linked to environmental changes in relation with air masses origin, to be the starting point for national and global mapping.

3. Isotopic results at the Orsay station

We present here the $\delta^{18}O/\delta^{2}H$ values of precipitation obtained since 2002 at the Orsay station (48.7°N/ 2.18°E). This is one of the longest isotopic time-series of precipitation in France. Located in the middle of the Paris-Basin, this station is run by the hydrological group of GEOPS laboratory at the University Paris-Saclay.

3.1. Fortnightly isotopic monitoring

The results highlight a high variability of fortnightly isotopic contents in rainfall with frequent abnormally negative or positive peaks compared to those expected at the sampling season.

Regarding the yearly rainfall and oxygen-18/deuterium contents over the last 20 years, we observe a positive trend in precipitation amounts of about + 70mm per decade and an opposite trend for isotopic contents with a depletion of the order of -0.7 ‰ per decade as well (Figures 3a and 3b). The temperature does not show a clear change, although since 2015 there has been a tendency for the temperature to increase steadily. Considering the deuterium excess and even if the values look irregular over the 20 years of measurements, a slight increasing trend in the d-excess values is noticeable, particularly over the period 2011-2021 (Figure 3c). Although the tendencies have to be confirmed with more annual data, it is possible that they are the expression of climate change occurring over the northern France (e.g. increasing impact over time of extreme events, continental vapor recycling, increasing part of Mediterranean vapor).

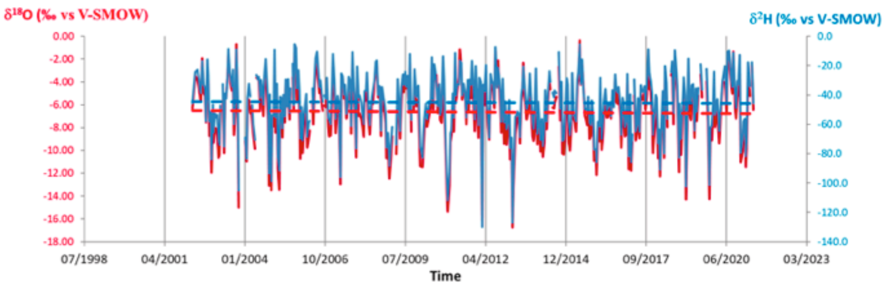


Figure 2: Twice monthly stable isotope contents in 2002-2020 precipitations at Orsay station (station of the French National Observatory for isotopes in precipitation – SNO RENOIR

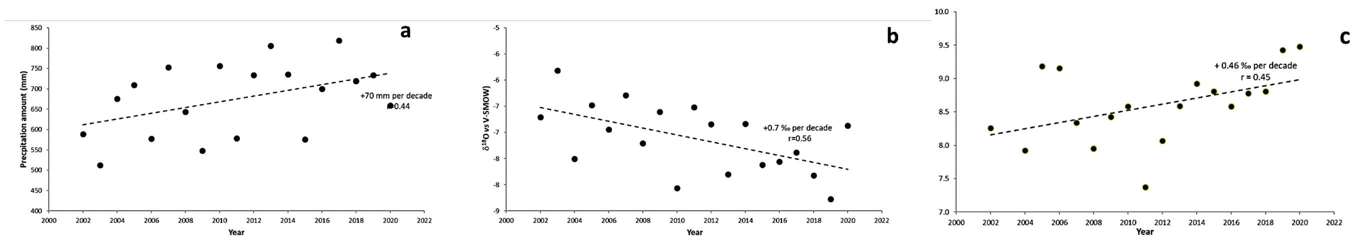


Figure 3: Yearly values of precipitation amount (a), $\delta^{18}O$ value (b) and d-excess (c) – Orsay Station (2002-2020)

3.2. First experiment of infra-event sampling

The stable isotopic composition of precipitation has been shown to be highly variable on temporal scales from rainfall event (even infra-event) to years. Concerning the Orsay data, the linking of the isotopic composition of

precipitation with the origin of the moist air masses is extremely delicate due to the fortnightly sampling time inducing a mixture for several rainy events which can have a wide range of isotopic composition.
Although it can be possible to provide estimated percentages of the original probabilities of those "mixed" air masses over the period [Allard, 2017], the improvement of the method by both statistical data processing and targeted measurements of rainy events (altitude of air condensation and processes, temperature) is therefore sought in this project, mainly through the monitoring and study of SOPs (Special Observing Period) during specific rain/snow event(s) such as extreme events. In the objective of being able to sample sub-rainy events, we have planned to set up in 2020 a specific experiment adapted from an automatic ISCO3700 sampler (Figure 4).
These specific sampling will be targeted (i) at Spring which is the period displaying the highest isotopic variability and (ii) in Autumn/Winter which is the period showing the highest deuterium excess values (above 10) that could be related to the recycling of continental vapor.
However, due to the COVID-19 pandemic, the equipment was only settled up at the end of May 2021 and the first storm event that we were able to sample at high frequency was that of June 4.

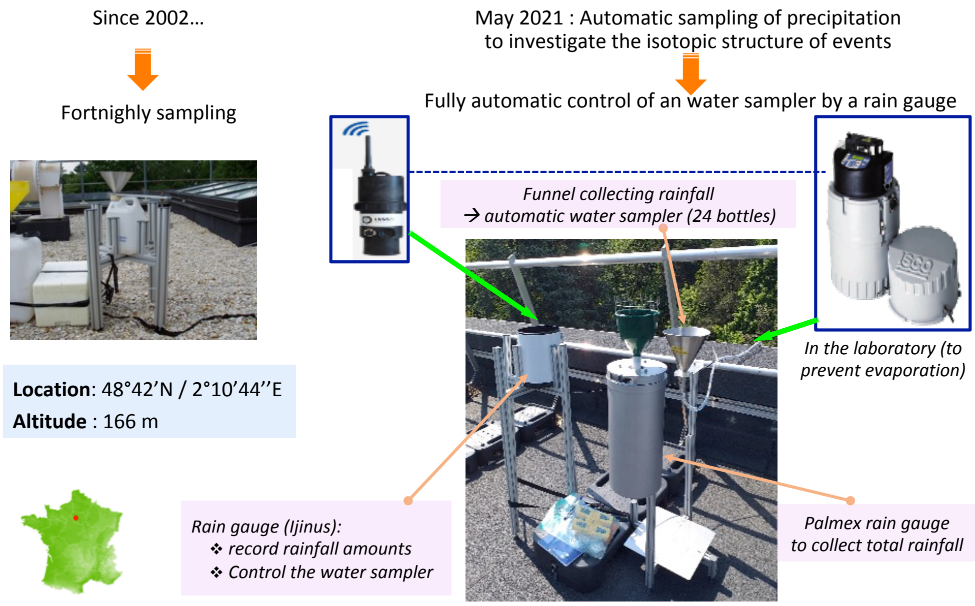


Figure 4: PALMEX and ISCO equipment's installed on the roof of our research building (Paris-Saclay University, Orsay-France)

The 4-June storm event (21.3 mm in 5 hours) was made of 3 independent showers (Figure 5).

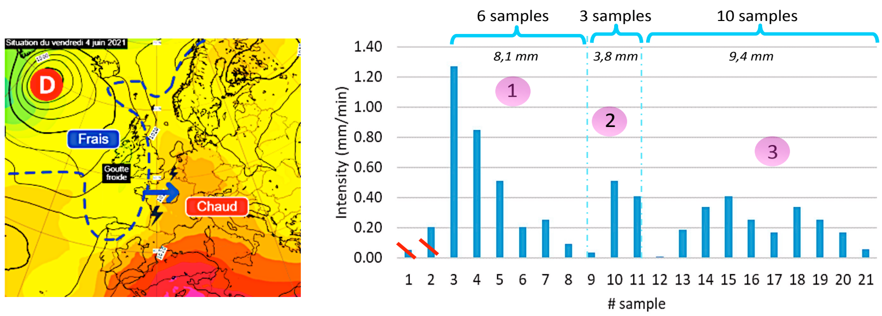


Figure 5: Daily meteorological pattern over Western Europe on 4th June, 2021 and corresponding storm event in Orsay

The results show that:

- ✓ There is a good agreement on total rainfall isotopic values, either measured or calculated: (i) results for the total event collected with the Palmex equipment ($\delta^{18}O$ = -4.43 ‰ and $\delta^{2}H$ = -24.4 ‰); (ii) results of the calculated cumulative precipitation of the sub-event samples collected in the ISCO equipment: ($\delta^{18}O$ = -4.33 ‰ and $\delta^{2}H$ = -24.4 ‰);
- ✓ There is a large range of isotopic values within this rainfall event of only 4 hours, i.e. ~ 3 ‰ for $\Delta\delta^{18}O$ and ~ 25 ‰ for $\Delta\delta^{2}H$;
- ✓ The general trend highlights a decrease in the stable isotope composition of the storm precipitation (amount effect?) as well as a washout effect highlighted with the inverse relationship between electric conductivity measured on rain water and rainfall intensity;
- ✓ The isotopic « structure » is variable between the 3 showers.

On the d-excess vs time evolution, the results indicate a value slightly above 10 on the whole event sample. However, within the storm, some d-excesses are sometimes relatively high compared to the average d-excess value. This evolution could be interpreted as the occurrence of several air masses from various origin (Mediterranean vs Atlantic vapors), get mixed at different atmospheric heights, such as, and/or even the contribution of recycled continental vapor.

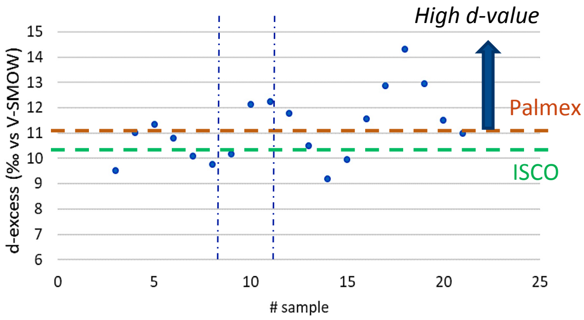


Figure 5: d-excess vs time (= # samples) diagram

The complex origin of air masses is confirmed by the determination of the atmospheric backward trajectories using HYSPLIT/NOAA software (Figure 6):

- Time parameter: 72 h;
- Altitude parameters: A- 2000 m AGL and B- 500 m AGL

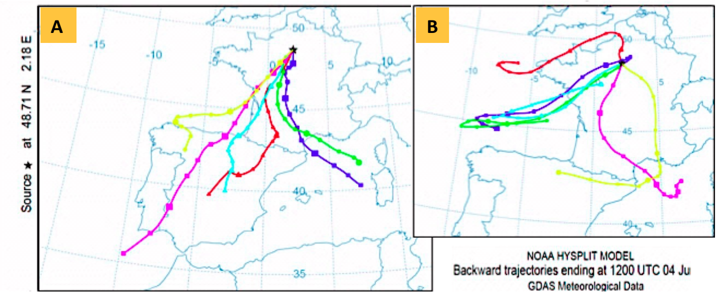


Figure 6: outputs of HYSPLITT modeling for the event of June 4, 2021 (http://ready.arl.noaa.gov/HYSPLIT.php)

4. Conclusion

Within the framework of this CRP and although our commitment in the project was based on all RENOIR stations, the pandemic didn’t allow us to work as planed with our colleagues.

We have pursued the monthly isotopic monitoring on Orsay station. As presented above, we can extract long-term trends from these data, which have yet to be interpreted, particularly in relation with climate change. Does the annual change in time show the impact of a larger/continuously increasing mass effect?

Moreover, parallely to the continuous record of $^{18}O/^{2}H$ in precipitation, we have developed a specific methodology for investigating isotopic structures of individual rainfall events. The first results are promising for both climatic and hydrological work (eg flood monitoring), in relation with the protection against climatic risks and hazards.

5. References

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