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Investigating long-term climate records to discern candidate extreme events in regions dominated by grasslands

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INTRODUCTION

Semi-natural grasslands tend to be more resilient to drought than croplands, but ongoing climate change may impact both their production and species composition. Impacts could thus concern the agronomic, patrimonial and ecological ecosystem services they provide. Climatic change is expected to mainly impact temperatures and water availability, including their variability within and between years, average values and critical periods for vegetation. However, specific temperature and rainfall patterns that may represent climatic extremes, remain largely unknown, along with their effects on vegetation production and plant species diversity.

This poster presents the initial phase of an investigation focused on identifying climatic patterns. We analysed long-term climatic data for two regions, Auvergne (31 years) and Marais poitevin (37 years), where semi-natural grasslands are the dominant land use. **Our goal was to determine** whether extreme climatic conditions could be distinguished in the time-series data, The analysis focused on yearly contrasts and seasonal patterns for two locations within each region.

Datasets

Climatic data were collected from Theix (63) and Marcenat (15) in Auvergne (sourced from INRAE: <https://agroclim.inrae.fr>), and from Niort (79) and La Roche-sur-Yon (85) in Marais Poitevin (sourced from MétéoFrance: <https://meteo.data.gouv.fr/datasets/donnees-climatologiques-de-base-quotidiennes>).

Selected raw variables were daily measures for precipitation (mm), potential evapotranspiration (PET; mm) and air temperatures (min, mean, max; °C). Climatic data started in 1985 (La Roche), 1986 (Theix, Niort) or 1991 (Marcenat) up to 2023 and were thus available for 31 to 37 years

Agro-Climatic criteria

- Average daily temperatures (min, avg, max) over the different periods and seasons (with winter [December year-1 to February y], spring [March – May], summer [June – August] and autumn [September – November]).
- Start of Growing Season: date of the year when the cumulative sum of °C reaches a threshold (200 °C or 350 °C). The sum of degrees starts on 1st January and ignores negative values.
- Heatwave: A period of at least seven consecutive days during which the daily maximum temperature exceeds the seasonal mean maximum temperature by 3 °C. It is described by its duration, frequency and intensity. Duration is the maximum count of consecutive days with Tmax > mean Tmax + 3.0 °C (baseline temperature) (Matthews et al., 2008). Frequency is the total count of days when Tmax > mean Tmax and Intensity is the sum of °C above baseline temperature.
- Climatic water balance: sum of precipitation minus sum of PET over the period. Prior to calculations, daily values are smoothed by averaging over 30 days (Luna et al., 2023). We used the R package 'SPEI' (Beguería & Vicente-Serrano, 2023), based on the work of Vicente-Serrano et al. (2010).

RESULTS

1- Auvergne region: are there any extreme climatic conditions at Theix over time?

The maximum daily temperature increased significantly along the time-series in all four sites (e.g. 0.04-0.05 °C yr⁻¹ at Theix).

The magnitude of this T° increase is greatest in summer and autumn (Fig.1).

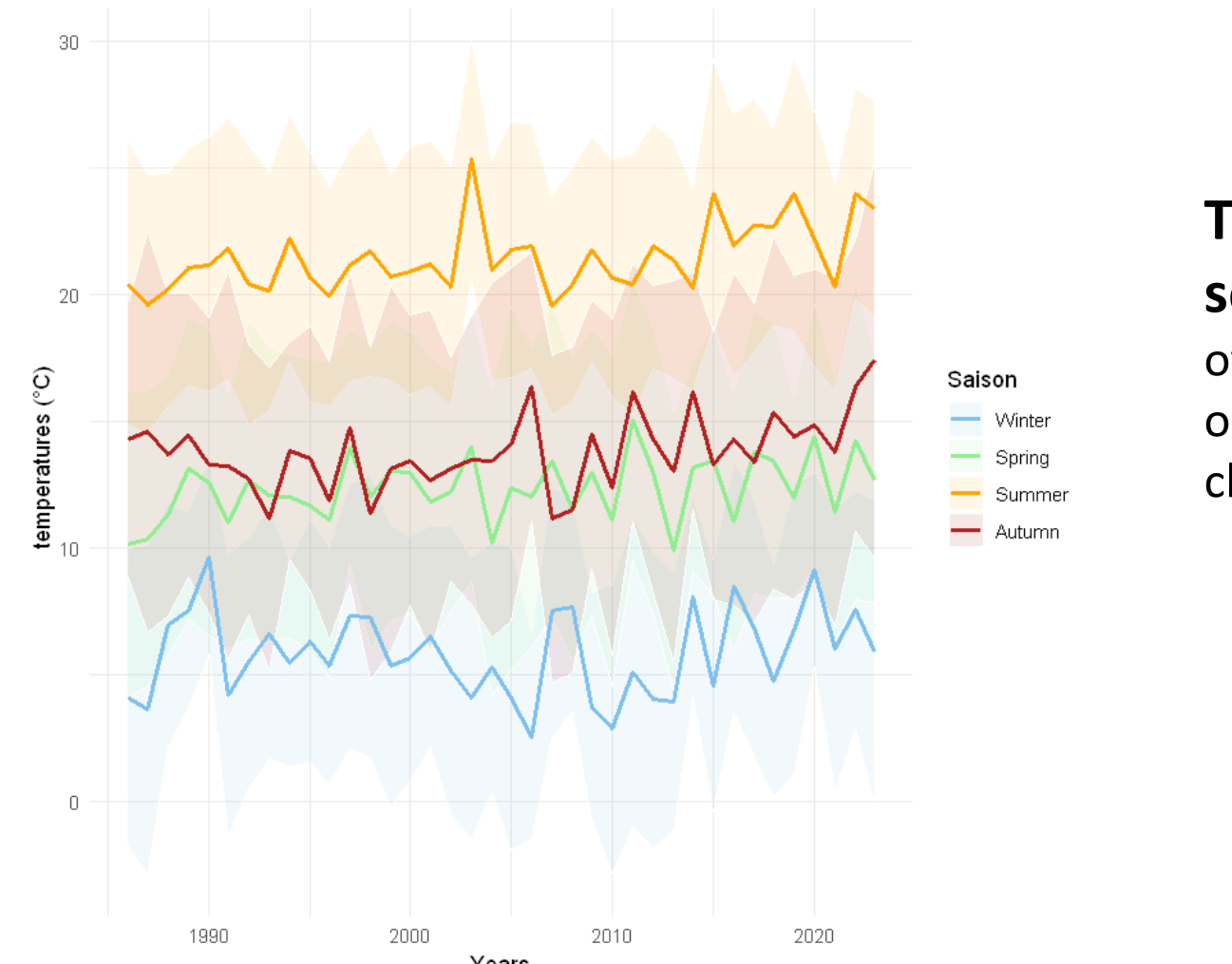


Fig. 1: Maximum daily temperature (1986-2023) at Theix (63), Auvergne (seasonal means)

The date of the start of the growing season shows a large range of variation over the years (Fig. 2). Extreme values are observed all along the time-series with no clear trend across years.

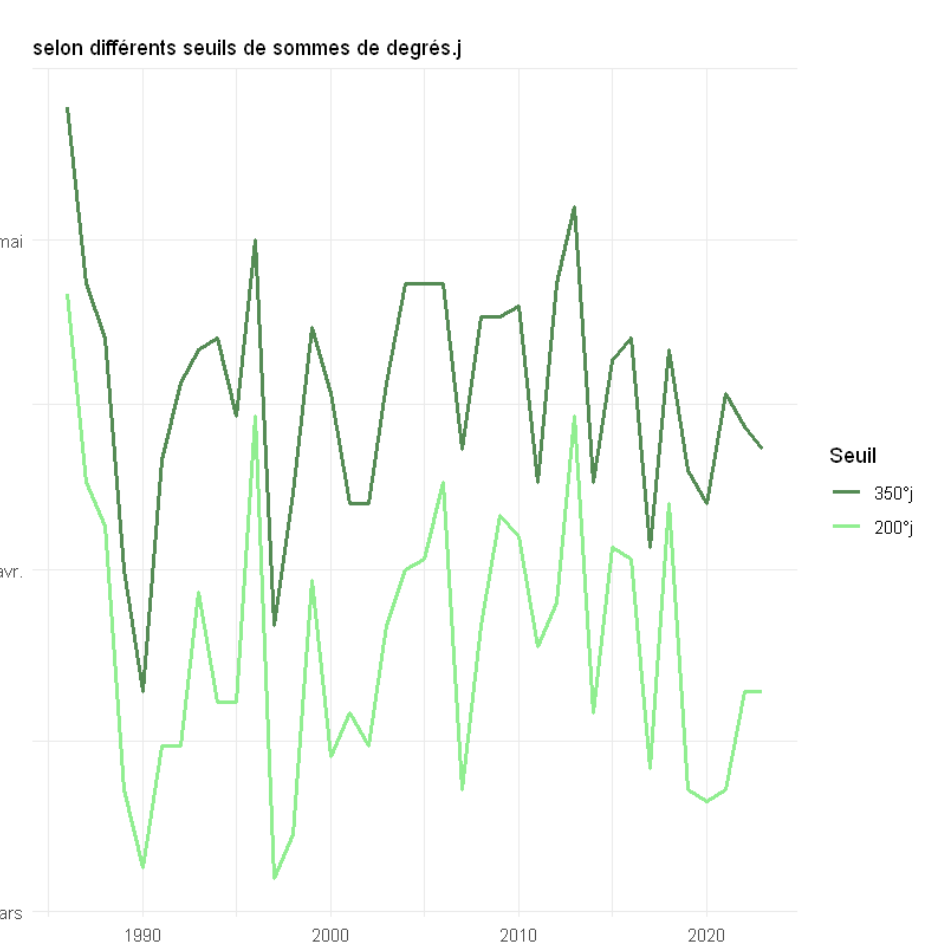


Fig 2: Sum of °C indicating start of growing season in Theix

Summer heatwaves last longer after 2000 than before (40% of heatwaves last more than 5 days before 2000 compared to 59% after 2000) (Fig. 3). Summer heatwaves have also tended to be more intense in recent years, with 41% of years after 2000 exceeding 70°C cumulative degrees, compared to 33% before 2000.

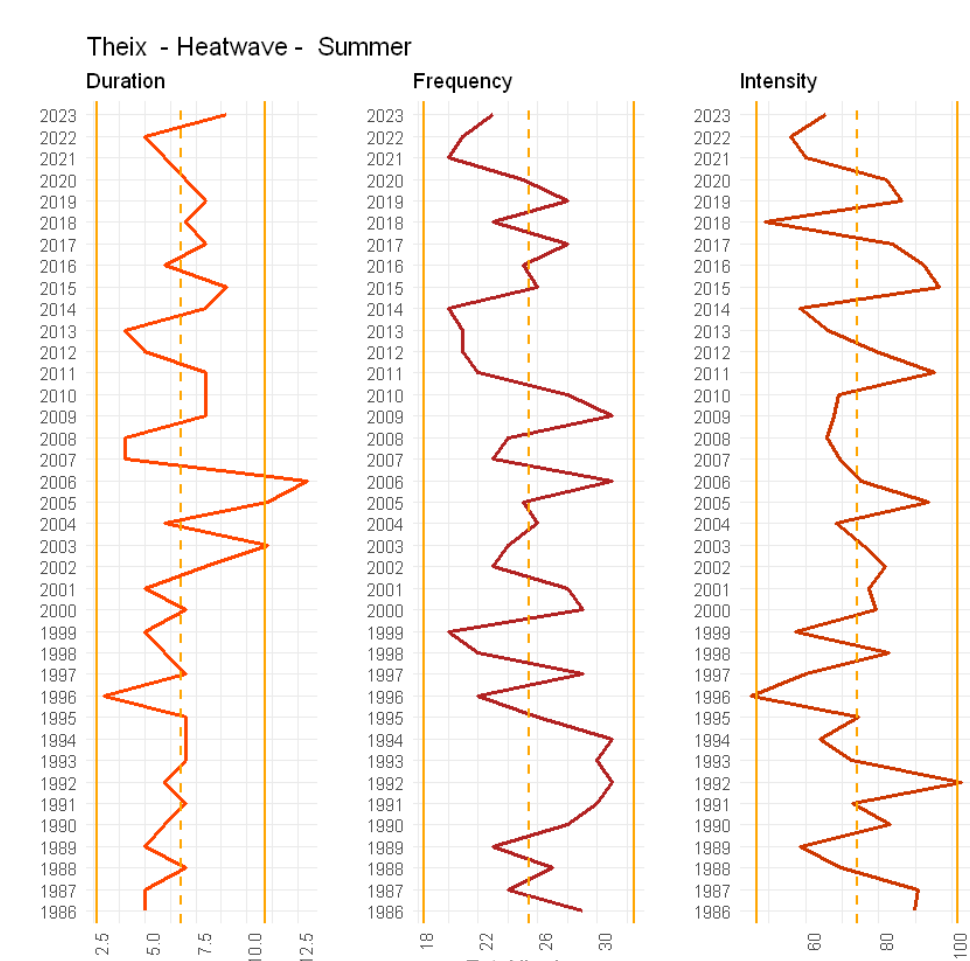


Fig 3: Summer heatwaves in Theix : duration, frequency and intensity from 1986 to 2023

Climatic water balance (P-ETP)

The annual water balance (P-ETP) was less positive after 2000 (about half of the years) than before 2000 (73%).

Together, large positive values of WBAL (e.g. > 250 mm) become increasingly rare (1/22 against 3/14 years) post 2000.

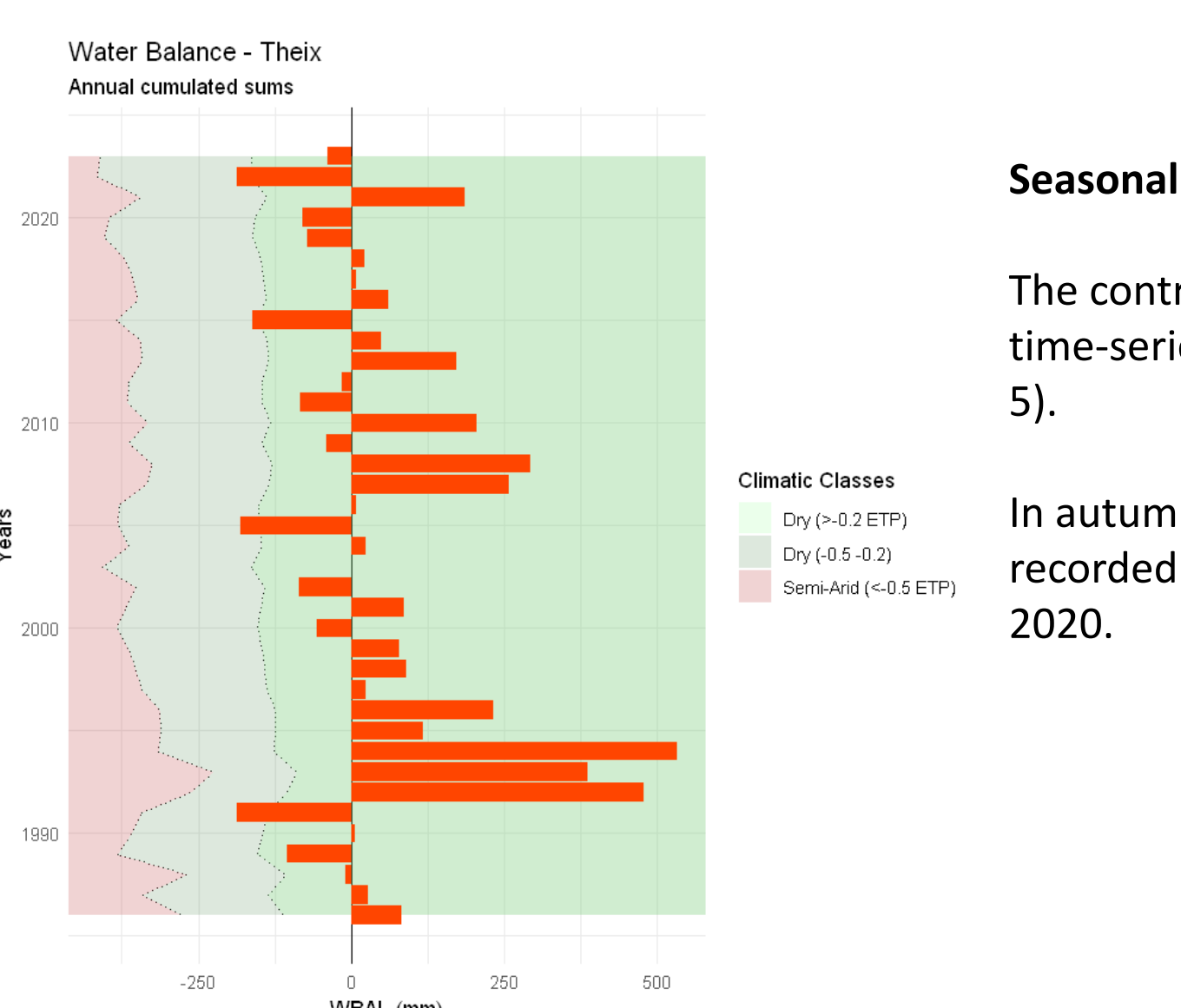


Fig 4: annual water balance (cumulated P-ETP) at Theix, 1986 to 2023

Seasonal patterns

The contrasts in the water balance along the time-series mainly concern the autumn (Fig. 5).

In autumn, only one negative value was recorded before 2000 compared to 7 after 2020.

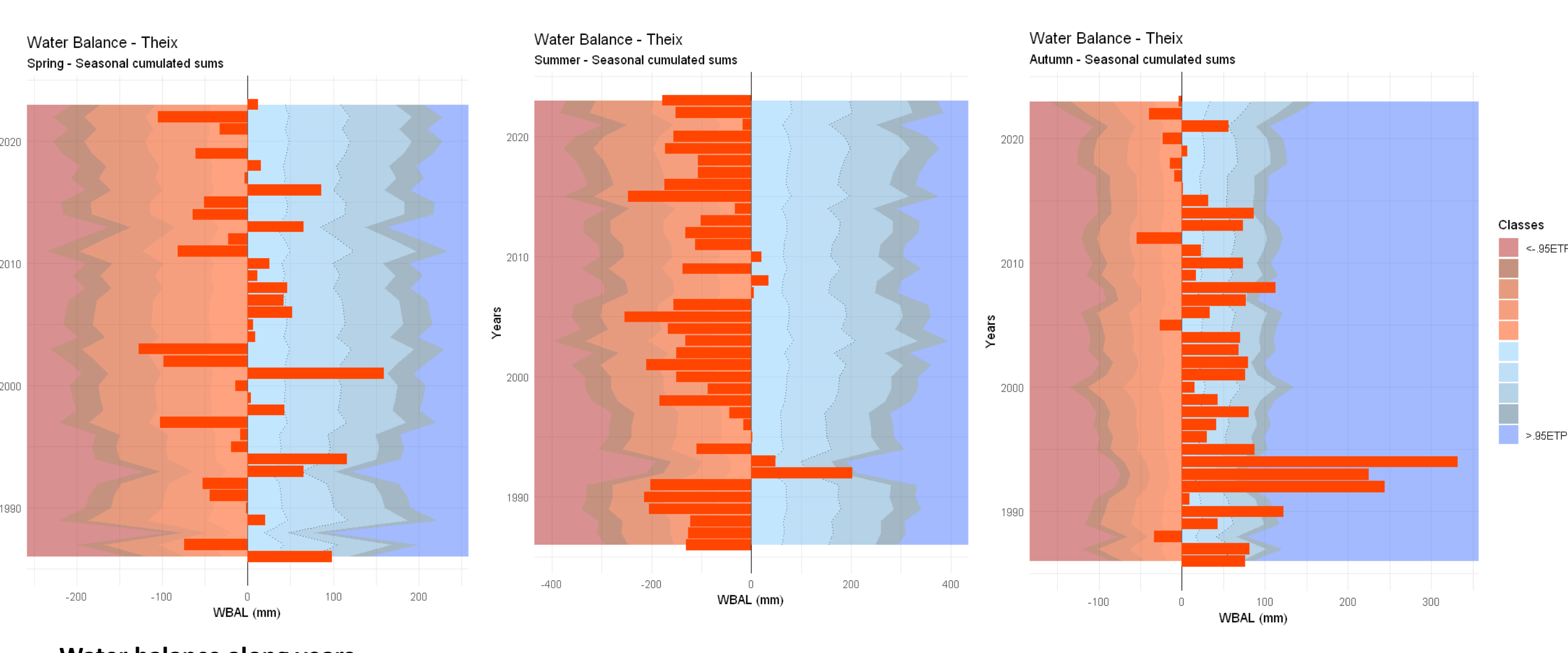


Fig. 5: Seasonal water balance (cumulative P-ETP) at Theix from 1986 to 2023 : spring, summer, autumn

2- Contrasts between regions ? Niort (Marais poitevin) compared to Theix (Auvergne)

Maximum Daily Temperatures

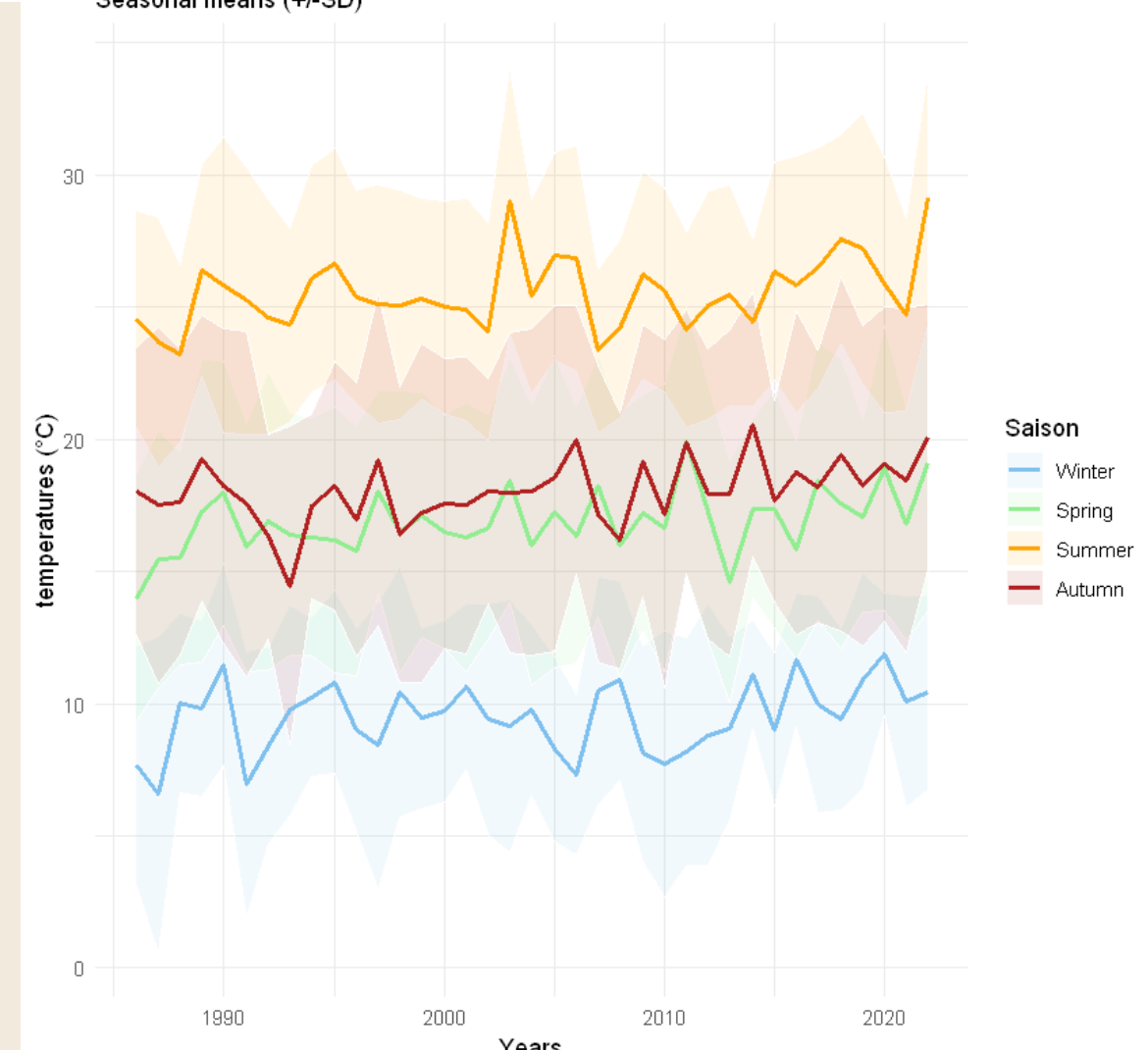


Fig. 6: Maximum daily temperature at Niort (Marais poitevin) from 1986 to 2023

Maximum daily temperatures at Niort increase at a similar rate than at Theix, with some differences between the seasons (Fig. 6).

Mean annual temperatures at Niort (Marais poitevin) increase more rapidly over the time-series than in Theix (+0,046 °C yr⁻¹ in Niort).

No clear pattern was found for the date of the start of the growing season in Niort (data not shown).

Heatwaves : unlike at Theix, Niort has not recorded any increase in the duration, frequency or intensity of summer heatwaves.

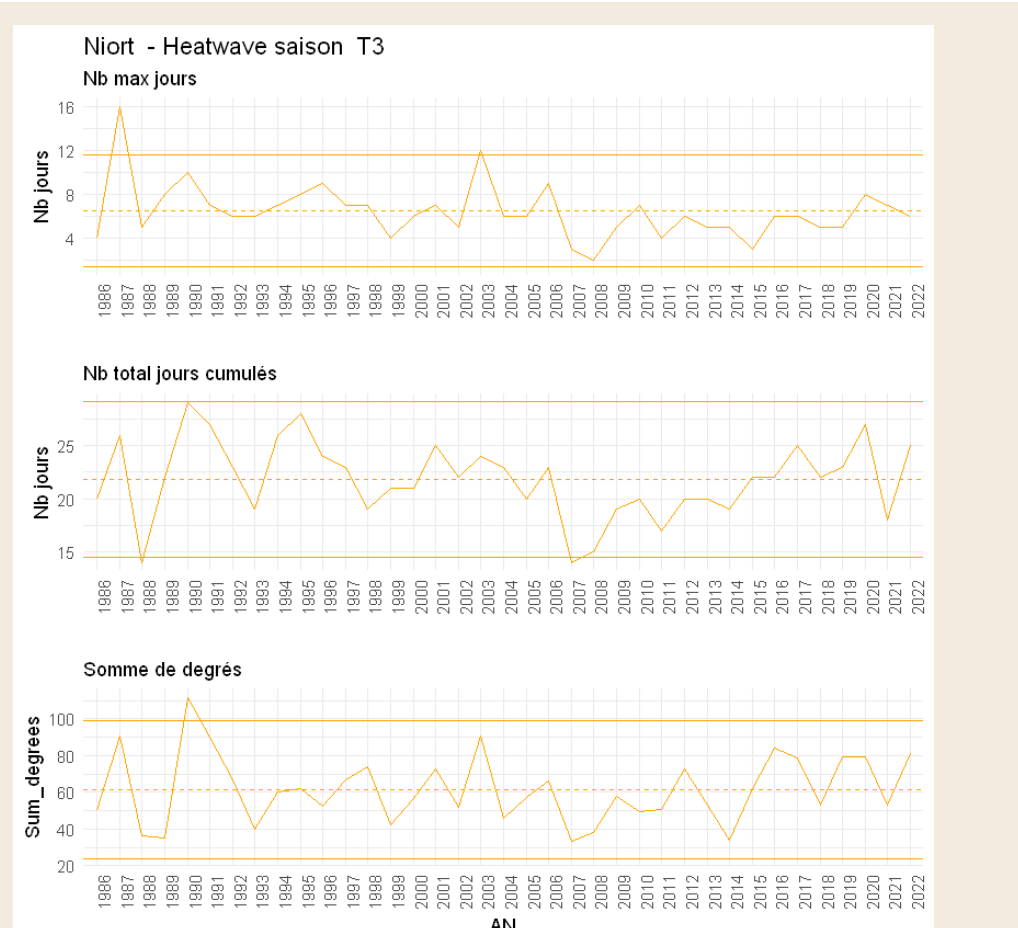


Fig. 7: Summer heatwaves metrics at Niort (Marais poitevin) from 1986 to 2023.

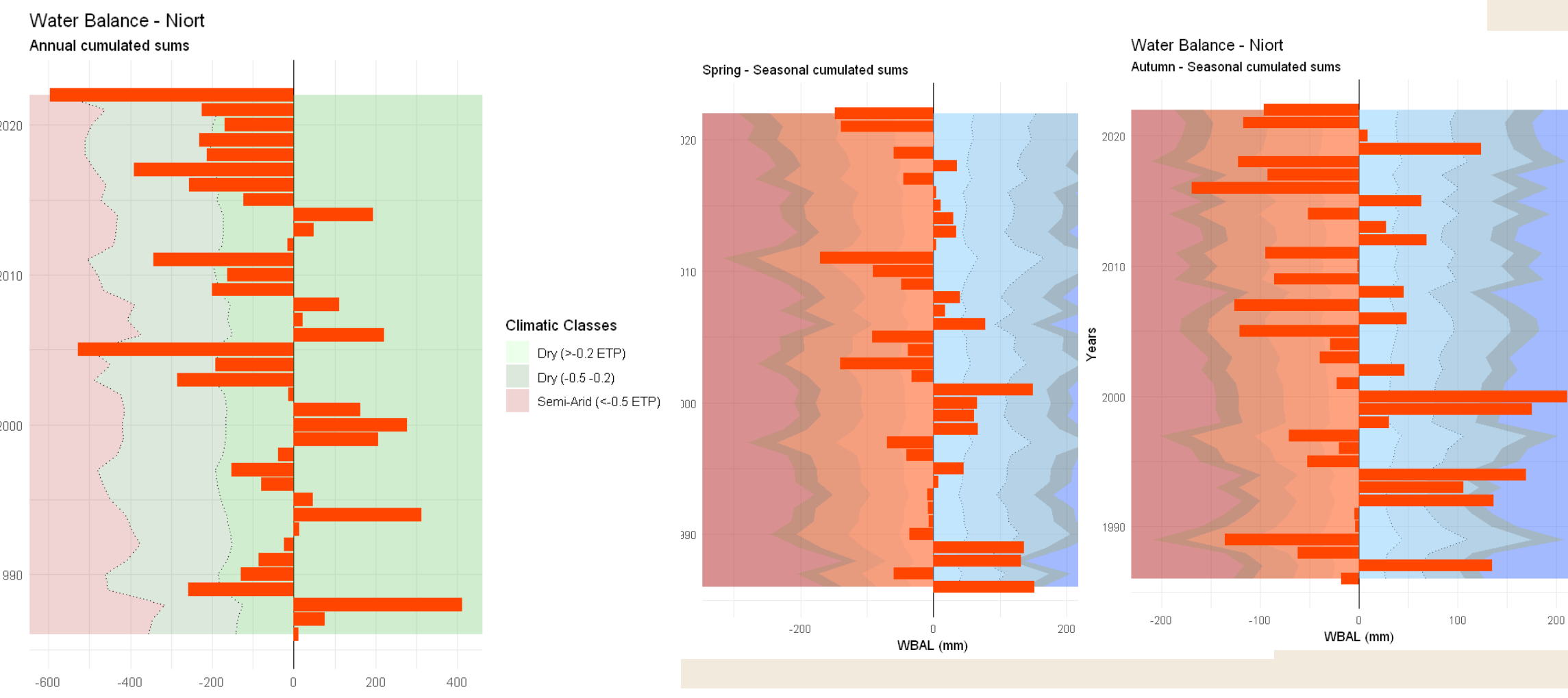


Fig 8: Water balance at Niort from 1986 to 2023: Annual pattern, spring and autumn

Water balance: Larger changes were recorded in Marais poitevin region than in Auvergne (Theix), with an increase in aridity. The changes concern the annual pattern (Fig. 8a), driven by changes in spring (Fig. 8b), autumn (Fig. 8c) and winter water balance, but not summer (data not shown).

Spring water balance was less frequently positive after 2000 than before (39% vs 57%), and high water deficits of -100 mm occurred in almost half of the springs after 2000, and none before. **Winter**, like **autumn**, was less likely to be highly positive (e.g. > 200 mm) after 2000 (21%) than before (42%).

3- Do climate extremes and trends differ within regions?

- The maximum daily temperature, heatwaves and starting date of the growing season were found to be similar for the two sites in Auvergne.
- They differ in their water balance patterns, reflecting the higher elevation of Marcenat (1075 m a.s.l.) compared to Theix (809 m) and the oceanic influence. Accordingly, the water deficit was much smaller at Marcenat, with a constant positive annual water balance from 1993 to 2023 (Fig. 9), in contrast to Theix (Fig. 4).
- The summer water deficit in Marcenat increased after 2000, being more frequent and intense than before (Fig. 10).

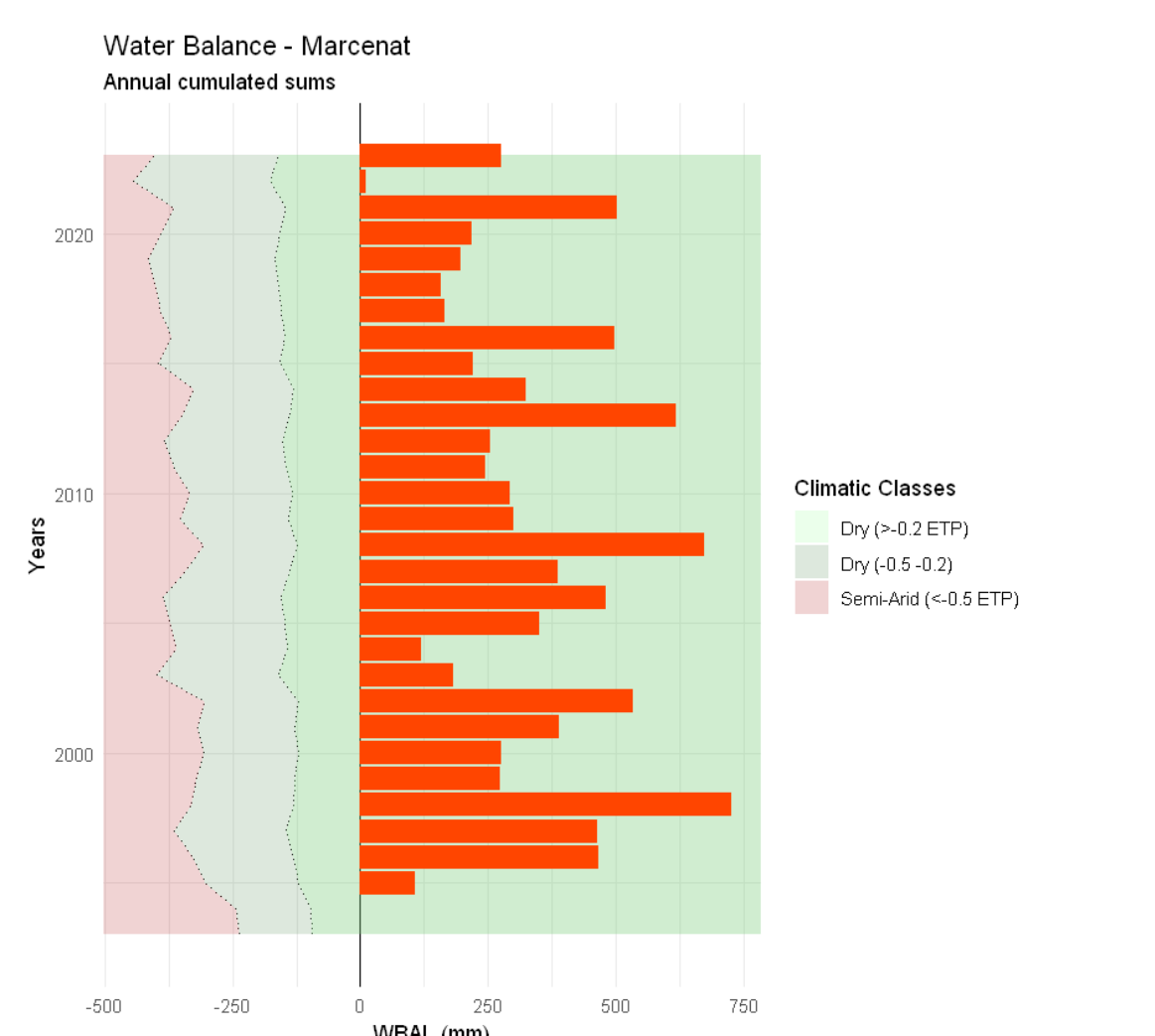


Fig. 9: Annual water balance in Marcenat (Auvergne)

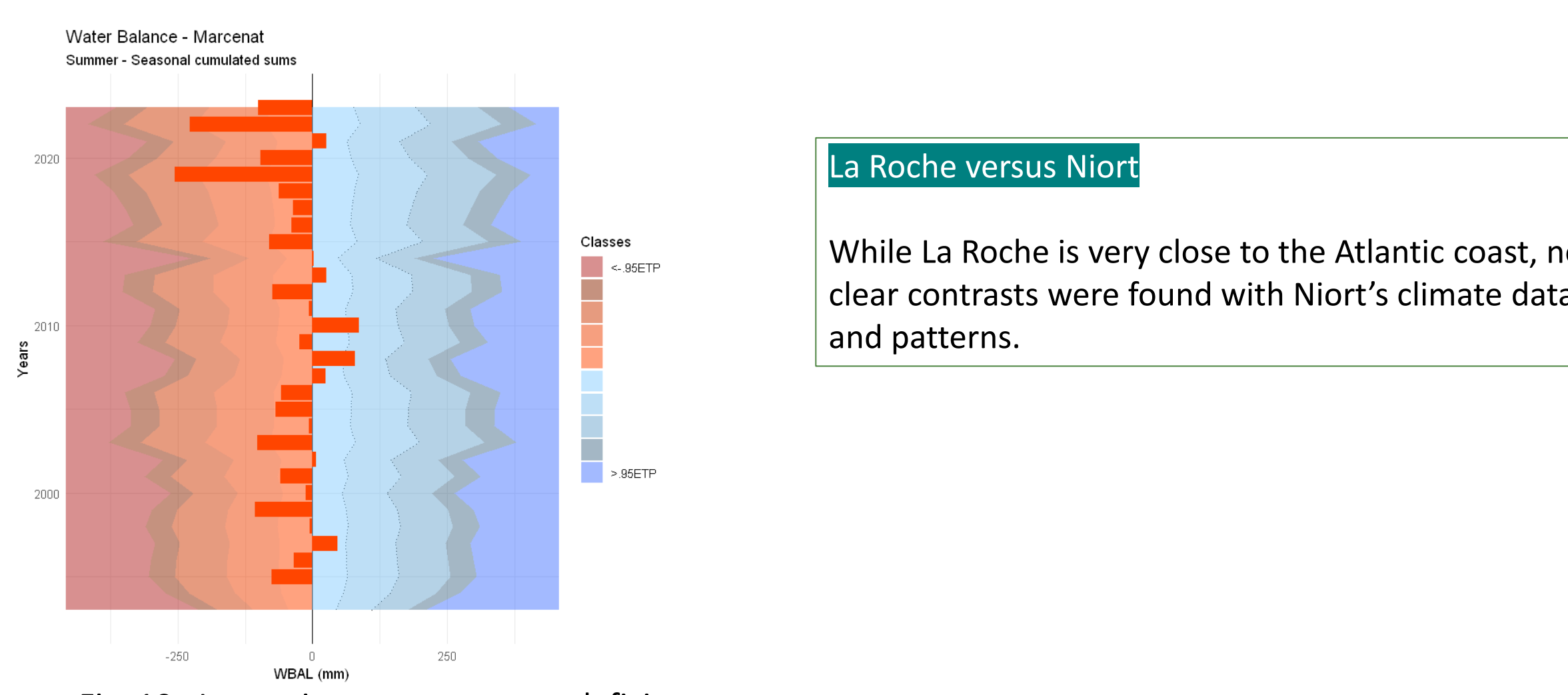


Fig. 10 : Increasing summer water deficit in Marcenat

La Roche versus Niort
 While La Roche is very close to the Atlantic coast, no clear contrasts were found with Niort's climate data and patterns.

DISCUSSION and PERSPECTIVE

- Climatic extremes were identified, along with notable changes over time, despite the limited time-series considered.
- A period of change towards higher temperatures and increased aridity appears to have started around the year 2000 in all four locations studied. In addition, the intensity and frequency of summer heatwaves, have increased, consistent with findings by Perkins-Kirkpatrick et Lewis (2020).
- The observed patterns were consistent both between and within regions, with differences between the two Auvergne sites related to well-known climatic drivers, such as altitude and oceanic influences.
- The effects of observed changes in climate on grassland plant biomass production and species composition are influenced by soil water resources and the soil's water storage capacity.
- Some results from the literature provide insights into the potential effects of water deficits on grassland productivity. For instance, in Auvergne, Zwicke et al. (2013) found that a water deficit of 180 mm during the growing season increased leaf senescence and reduced primary production in grasslands. In southwestern France, Poirier et al. (2012) reported that the critical hydraulic deficit impacting tiller survival varied from -700 to -500 mm, depending on whether the grass variety was Mediterranean or temperate.
- Such knowledge still needs to be adapted to the local flora in a variety of semi-natural temperate grasslands.
- The impact of such climatic contrasts on species composition and the relative abundance of plant communities in grasslands remains to be investigated.
- In marshland sites, such as parts of the Marais poitevin (Bonis et al., 2023; Mauchamp et al., 2024), anthropogenic water regime management may either mitigate or exacerbate the effects of climate changes. However, the effects of such interactions on water availability for plants, grassland productivity and plant communities are still largely unexplored.

Perspectives

The second part of this project will investigate whether the climatic signals of change identified are accompanied by shifts in grassland biomass production and plant species composition in the two study regions.

This will be achieved using both experimental data on rain interception design and *in situ* observational data collected over a multi-year time frame.

We hypothesise that extreme water deficits and increased heatwave intensity will affect grassland biomass and species composition. These effects are expected to be mediated by soil water-holding capacity at all sites and by water regime management in marshlands areas.