Chapter 74
Impacts of Climate Change on Water Availability for the Vésubie Catchment, France

Masoud Ghulami, Philippe Gourbesville, and Philippe Audra

Abstract To understand the future changes of water resources and its impact assessments, it is necessary to have reliable projections of temperature and precipitation. A high-resolution regional climate change ensemble is available for Europe within the World Climate Research Program Coordinated Regional Downscaling Experiment (EURO-CORDEX) initiative. These simulations should be validated against observations before they can be used in hydrological models or other assessment tools. The Vésubie canal is a 32-km-long hydraulic structure built between 1851 and 1885. It allows the water from the Vésubie catchment to be channeled through Saint-Jean-la-Rivière to the city of Nice to supply the drinking water. The construction itself was quite complicated due to the complex geography, which required the construction of a siphon, numerous tunnels, and aqueducts to ensure a path whose regular topography ensures the transit of water without turbulence. The future changes in climate variables can affect the precipitation values and patterns over the Vésubie catchment. These changes would cause extreme precipitation events such as the recent flood in October 2020. In contrast, these changes in the hydrological cycle, when associated with a reduction in precipitation during the dry period, can lead to a reduction in flows generated from the Vésubie and thus limit the possible withdrawals. Therefore, in this research the following questions are answered: What are the future changes in precipitation and temperatures according to the different climate models and the different scenarios? What are the impacts of these changes on the availability of water resources? To answer these legitimate questions, the proposed approach is based on a distributed deterministic hydrological model with which the different reference evolution scenarios are simulated.

M. Ghulami (✉) · P. Audra
Polytech Lab, University of Côte d'Azur, 930 route des Colles, 06903 Sophia-Antipolis, France
e-mail: masoud.ghulami@unice.fr

P. Gourbesville
Polytech Lab, Université Côte d'Azur, Sophia Antipolis, France
e-mail: philippe.gourbesville@univ-cotedazur.fr

China Institute of Water Resources and Hydropower Research, Beijing, China

P. Gourbesville and G. Caignaert (eds.), *Advances in Hydroinformatics*, Springer Water,
https://doi.org/10.1007/978-981-19-1600-7_74

Keywords Climate change · EURO-CORDEX · Vésubie catchment · Precipitation patterns

74.1 Introduction

The territory of the Nice Côte d´Azur metropolis benefits from multiple water resources—surface and underground—which supply the inhabitants of the various municipalities. Four catchment fields take water from the Var aquifer while a fifth, in Cagnes-sur-Mer, takes water from the Loup aquifer. Fourteen sources are also captured on Duranus, Coaraze, La Gaude, Saint-Jeannet and Vence. The waters of the Vésubie are collected in Saint-Jean-la-Rivière and are transported, via the Vésubie canal, to the Nice.

Today these resources make it possible to meet the needs on the territory of the NCA Metropolis. However, the various simulations carried out for climate change in the south-eastern region of France, highlight the possible increase in temperatures and the duration of periods of drought. This development could potentially affect hydrological conditions and impact the volume of water resources. In this context, the water abstracted from the Vésubie could be reduced due to the reduction of flows associated with the restriction of the reserved environmental flow.

To assess the possible impact of climate change on the water resource from the Vésubie catchment, the simulation of reference climate scenarios using a distributed hydrological model would make it possible to anticipate this change and to reflect on the different strategies that could be implemented to ensure the water supply of the municipalities downstream of the territory of the NCA Metropolis.

74.2 Methods

74.2.1 Study Area and Available Data

The Vésubie catchment is a part of Var basin and its water is used to supply the drinking water to the city of Nice through a canal, initially built more than 145 years ago (Fig. 74.1; Table 74.1).

The Vésubie canal is a 32-km-long hydraulic structure built between 1851 and 1885. It allows the water from the Vésubie to be channeled through Saint-Jean-la-Rivière, to the town of Nice to supply the drinking water. It was built on very complex topography and therefore required the construction of a siphon, numerous tunnels, and aqueduct to ensure a path whose regular topography ensures the transit of water without turbulence (Fig. 74.2).

The discharge measurements are available for this canal at Utelle (Pont du Cros). There are several weather station also with longterm observations (Table 74.2; Figs. 74.3 and 74.4).

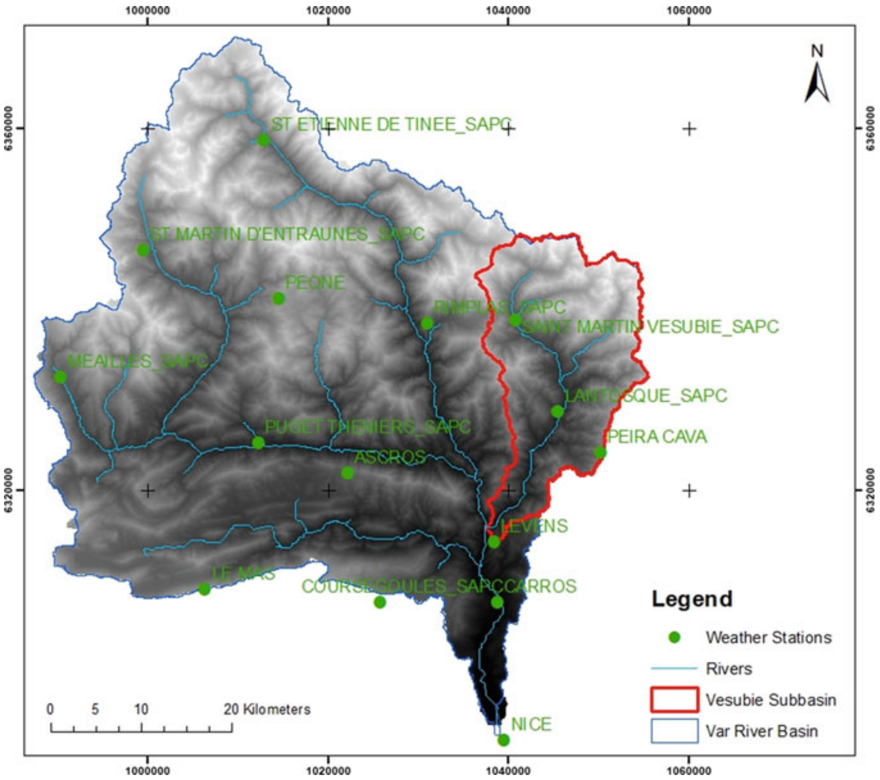

Fig. 74.1 Vésubie catchment in the Var basin

Table 74.1 Characteristics of the Vésubie catchment

Catchment	Area (km^2)	Elevation range (m)	Maximum slope (°)	Median slope (°)
Vésubie	392.36	132.43–3132.07	79.98	31.21

74.2.2 *Climate Change Data*

For this study, a Multi-RCMs approach was used to identify the uncertainty in a climate change model for predictions of future precipitation and temperature for the Vésubie catchment (Table 74.3).

The delta change approach is a method to downscale global/regional climate model data so that this data may be used as an input for hydrological models [1]. Climate model outputs have inadequacies and a common approach to deal with that issue is the delta change method. This method computes differences between current and future GCM/RCM simulations and adds these changes to the observed

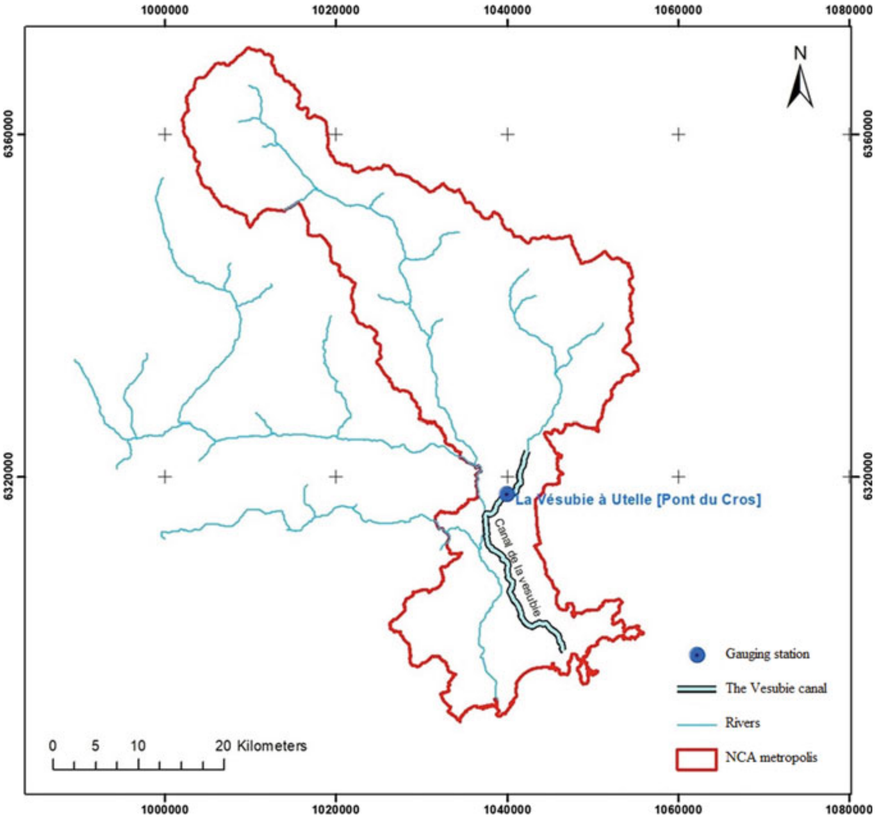

Fig. 74.2 The Vésubie canal

Table 74.2 Weather stations in the Vésubie catchment (*Source* Météo-France)

Station	ID number	Daily data	Hourly data	Altitude (m)
LANTOSQUE	6,074,005	Yes	Yes	550
PEIRA CAVA	6,077,006	Yes	No	1443
ST-MARTIN-DE-VESUBIE	6,127,001	Yes	No	994

time series. The delta change method is the primary future scenario generation technique suggested for use in the U.S. National Assessment. Applying the delta change method assumes that GCMs/RCMs more reliably simulate relative changes rather than absolute values [2].

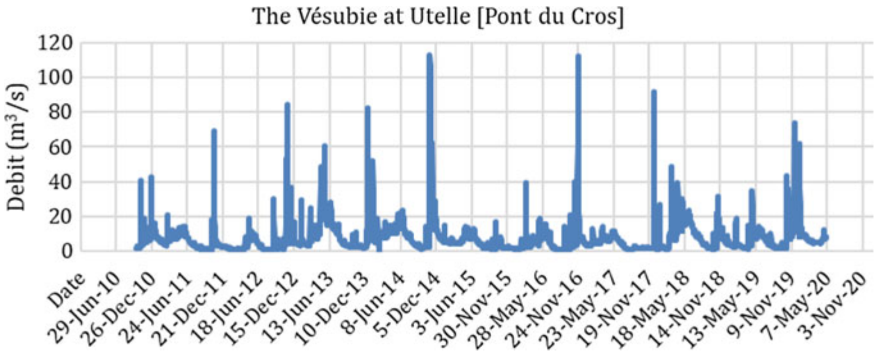

Fig. 74.3 Daily discharge at Pont du Cros (*Source* Banque HYDRO)

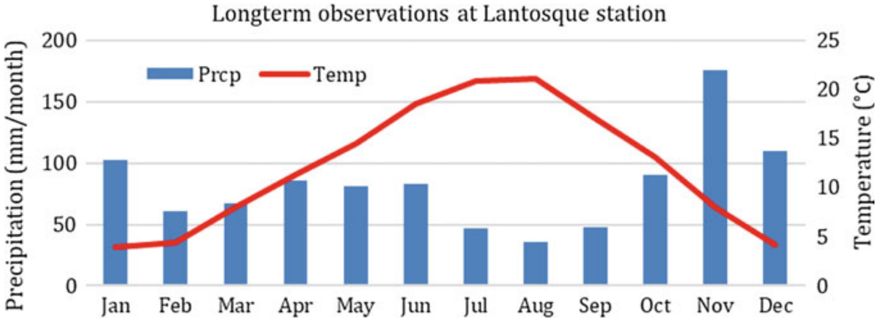

Fig. 74.4 Longterm values of average monthly precipitation and temperature for the Lantosque station (*Source* Météo France)

Table 74.3 List of EURO-CORDEX-RCMs used in this study

ID	RCM	Resolution	Contributing institute
1	CNRM-CERFACS-CNRM-CM5	0.11° × 0.11°	SMHI
2	ICHEC-EC-EARTH	0.11° × 0.11°	SMHI
3	IPSL-IPSL-CM5A-MR	0.11° × 0.11°	SMHI
4	MOHC-HadGEM2-ES	0.11° × 0.11°	SMHI
5	MPI-M-MPI-ESM-LR	0.11° × 0.11°	SMHI

74.2.3 MIKE SHE Deterministic Hydrological Model

The first step is to determine the type of model that should be implemented given the objective to be achieved. Given the physical nature of the processes present in hydrosystems, the deterministic approach—based on the laws of physics—should be favored.

The massive data acquisitions made in recent years in the lower Var valley now allow the deployment of deterministic modeling covering the different elements of the water cycle in the lower Var valley. Advances in numerical computation today make this approach realistic. A deterministic modeling will therefore be privileged in this project. Deterministic hydrological modeling at the watershed scale for the evaluation of climate scenarios.

The hydrological model developed by Ma [3] for the AquaVar project is built with MIKE SHE software, which allows the water cycle to be modeled in the Vésubie catchment, for a total area of 392 km^2. The current hydrological model is densified and tested based on the flow measurements at the Pont du Cros hydrometric station.

Developed by DHI, MIKE SHE is a deterministic modeling system that simulates the water cycle in a watershed. The equations are solved using the finite difference method according to a structured mesh. The digital model built with MIKE SHE is distributed and is physically based. It contains six modules including runoff, evapotranspiration, snowmelt, saturated/unsaturated flow, and surface flow. Each represents a part of the water cycle process.

74.3 Results

74.3.1 Future Changes of Temperature and Precipitation

The RCMs' values were compared with their baseline observations (1986–2005) for each month and the changes were calculated for the whole Vésubie catchment. Figure 74.5 shows the median of all 5 downscaled RCMs. The results suggest an increasing trend in temperature in the future period of (2031–2050), as compared to the baseline. The increases in temperature range from +0.8 to +2.1 °C under RCP

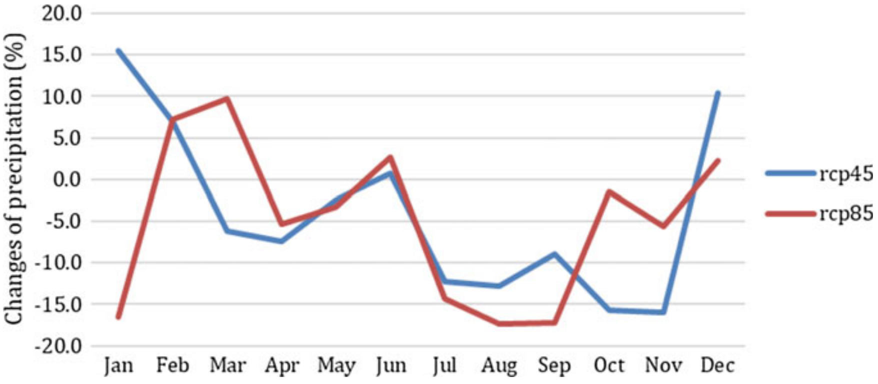

Fig. 74.5 Future changes of precipitation values for the Vésubie catchment in the period of (2031–2050) compared with the baseline of (1986–2005)

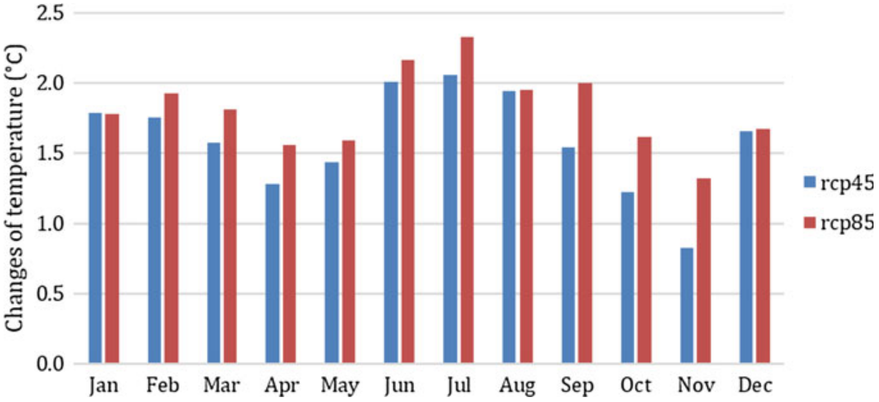

Fig. 74.6 Future changes of mean temperature values for the Vésubie catchment in the period of (2031–2050) compared with the baseline of (1986–2005)

4.5 and +1.3 to +2.3 °C under RCP 8.5. The projections for precipitation suggest an overall decreasing trend in the precipitation under both RCPs 4.5 and 8.5 (Fig. 74.6).

74.3.2 Future Changes of Water Availability

The simulations' results of future runoff were compared with the results of the model for the baseline period of 1986–2005. Figure 74.7 shows the percentage changes of future runoff for the period of (2031–2050) under different RCP scenarios based on the median of changes of all used RCMs. Overall, the results suggest that future runoffs are very likely to decrease. This is mainly due to the decrease in the precipitation (Fig. 74.8).

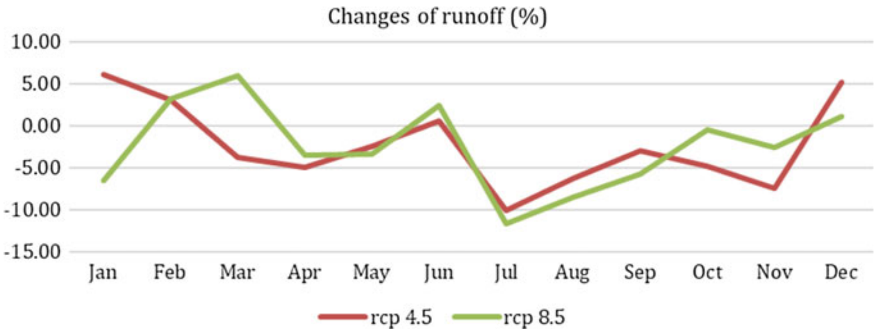

Fig. 74.7 Percentage of changes in the future runoff (2031–2050) compared to the baseline (1986–2005) for the Vésubie catchment

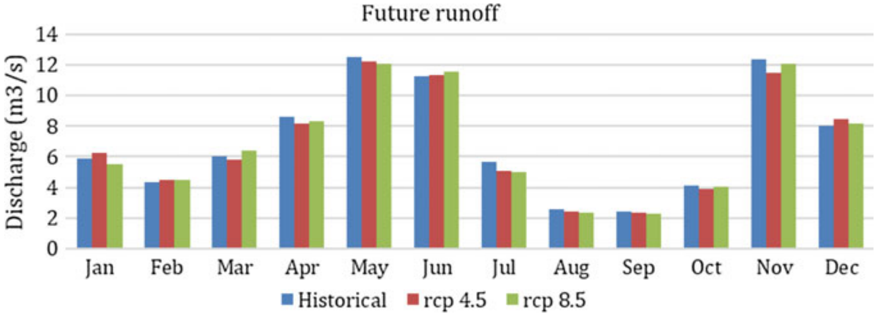

Fig. 74.8 Changes in the future runoff (2031–2050) compared to the baseline (1986–2005) for the Vésubie catchment

74.4 Conclusion

Based on the RCMs' values used in this study for the Vésubie catchment, an increasing trend in temperature is projected for the future period of (2031–2050) compared to the baseline (1986–2005). The increases in temperature range from + 0.8 to +2.1 °C under RCP 4.5 and +1.3 to +2.3 °C under RCP 8.5. The projections for precipitation suggest an overall decreasing trend in the precipitation under both RCPs 4.5 and 8.5.

The simulations' results of future runoff suggest a decreasing trend as compared with the baseline runoff. This is mainly due to the decrease in the precipitation. However, impacts of increasing temperature should be investigated as the contribution from the snowmelt process can be increased in the near future.

References

1. Ghulami M, Gourbesville P, Audra P (2020) Assessing future water availability under a changing climate in Kabul Basin. In: Advances in hydroinformatics. Springer, Singapore, pp 647–657
2. Hay LE, Wilby RL, Leavesley GH (2000) A comparison of delta change and downscaled GCM scenarios for three Mounfainous basins in THE UNITED STATES1. J Am Water Resour Assoc 36(2):387–397
3. Ma Q (2018) Deterministic hydrological modelling for real time decision support systems: application to the Var catchment, France (Doctoral dissertation, Université Côte d'Azur)