Interannual variability of seasonal water levels in the St. Lawrence River, Quebec

Variabilité interannuelle des niveaux d'eau saisonniers du fleuve Saint-Laurent au Québec

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RÉSUMÉ

Pour désenclaver la région des Grands Lacs en Amérique du Nord, au milieu du siècle passé, on a creusé un chenal maritime dans le lit mineur même du fleuve Saint-Laurent d'une part, et de nombreux barrages et écluses pour réguler les niveaux d'eau du fleuve et des Grands Lacs, d'autre part. Cette étude a pour but d'analyser les impacts de ces aménagements anthropiques sur la variabilité interannuelle des niveaux d'eau saisonniers du fleuve Saint-Laurent au Québec. Nous avons appliqué la régression linéaire et la méthode de Lombard pour déterminer la tendance à long terme et la stationnarité (moyenne et variance) des niveaux d'eau saisonniers mesurés à la station de Sorel depuis 1918. Ces méthodes ont révélé une diminution significative des niveaux d'eau moyens en hiver et au printemps. Cette diminution est survenue en 1957 à la fin de la construction du chenal maritime. La diminution des niveaux d'eau sera amplifiée dans l'avenir par le réchauffement climatique pourra ainsi entraîner de nombreuses conséquences morphologiques et écologiques au Québec.

ABSTRACT

In the mid-20th century, to open up North America's Great Lakes Region, a seaway channel was dug in the low flow channel of the St. Lawrence River, and numerous dams and locks were built to regulate water levels in the river an the Great Lakes. The study looks at the impact of these manmade structures on the interannual variability of seasonal water levels in the St. Lawrence River in Quebec. Linear regression and the Lombard method were used to constrain the long-term trend and stationarity (mean and variance) of seasonal water levels measured at the Sorel station since 1918. These methods reveal a significant decrease in mean winter and springtime water levels, which took place in 1957, after completion of seaway channel construction. In the future, this decrease in water levels will be enhanced by climate warming, which could have numerous morphological and ecological implications in Quebec.

KEYWORDS

Dams, Lombard method, Seasonal water levels, Seaway, St. Lawrence.

INTRODUCTION

Water levels in the St. Lawrence River play very important hydrological, ecological and morphological roles in Quebec. From a hydromorphological standpoint, the St. Lawrence is the base level for all its tributaries. Thus, any significant change in water level in the St. Lawrence may have an impact on its own hydrological (water quality), morphological, sedimentological and ecological evolution and that of its tributaries (Boyer et al., 2010). Hydrologically, a decrease in water level in the St. Lawrence would significantly reduce its ability to dilute all the pollutants derived from farming and industrial activities. From a morphological and ecological standpoint, a decrease in water levels would promote erosion and, consequently, increase sediment input from tributaries, which would affect the quality of plant and animal habitats. Finally, water level in the St. Lawrence affects the development and biodiversity of aquatic plants in riverine Lake Saint-Pierre, which in turn affects the food chain in this lacustrine ecosystem.In the mid-20th century, to open up North America's Great Lakes Region, a seaway channel was dug in the low flow channel of the St. Lawrence River. In addition, many dams and locks were built to regulate water levels in the river and the Great Lakes. However, no study has yet looked at the impact of these man-made structures on water levels in the St. Lawrence in Quebec. The goal of this study is therefore to analyze the interannual variability of seasonal water levels in the river to constrain any such impact.

METHODS

The St. Lawrence River, one of the largest rivers in the world, is also one of the Great Lakes main natural outlets. It flows along 3060 km and its watershed extends over 1 300 000 km^2, nearly half of which is in the Province of Quebec, Canada. To facilitate trade between the Great Lakes Region and other continents, a canal system was built along the Great Lakes and the St. Lawrence channel starting in 1954, known as the Great Lakes St. Lawrence Seaway System, a 3700 km-long seaway linking the Great Lakes to the Atlantic Ocean. It comprises 19 locks and several dams used to regulate water levels in Lake Ontario and the St. Lawrence. The dams, which were all built on the section of the St. Lawrence located between Cornwall and Montreal, are the Moses-Saunders, Long Sault, Iroquois and Beauharnois dams. St. Lawrence River water level data were taken from the Environment Canada website (http://www.wsc.ec.gc.ca/applications/H2O/HydromatD-fra.cfm, downloaded on March 20th, 2010). These data were collected at the Sorel station, which is located downstream from the Montreal town (downstream from these dams). Water level data were grouped into four seasons corresponding to the annual hydrological cycle in the Great Lakes Region: winter (January to March), spring (April to June), summer (July to September) and fall (October to December). For each season, seasonal mean values were calculated over the period from 1918 to 2008. Water level hydrologic series were analyzed using simple linear regression to constrain the long term trend, on one hand, and the Lombard method (Lombard, 1987) to constrain breaks in the mean and variance values of the hydrologic series, on the other. The Lombard method can also be used to constrain the exact timing of such breaks.

RESULTS

Lombard method results are shown in Table 1 and Figure 1. Significant changes in the mean values of winter and spring water levels are observed. These changes took place in 1957 for springtime water levels and in 1980 for winter water levels. In both cases, the change corresponds to a decrease in water levels over time (Fig. 1). The timing of the springtime levels change corresponds to the digging of the seaway channel (Fig. 1). As for the change in winter water levels, it is likely linked to the modes of management of dams and locks located upstream from the Sorel station, as no significant decrease in winter rainfall and streamflow is observed in the Great Lakes Region over this time interval.

Tableau 1. Values of Lombard's statistic (Sn).

Seasons	Mean			Variance		
	Sn	T1	T2	Sn	T1	T2
Fall	0.0105	-	-	0.0336	-	-
Winter	**0.1343**	**1979**	**1980**	0.0039	-	-
Spring	**0.0818**	**1955**	**1957**	0.0000	-	-
Summer	0.0063	-	-	0.0216	-	-

The value of Sn> 0.043, shown in red bold, is statistically significant at the 95% level.T1 and T2 are years corresponding to beginning and end, respectively, of change in mean.

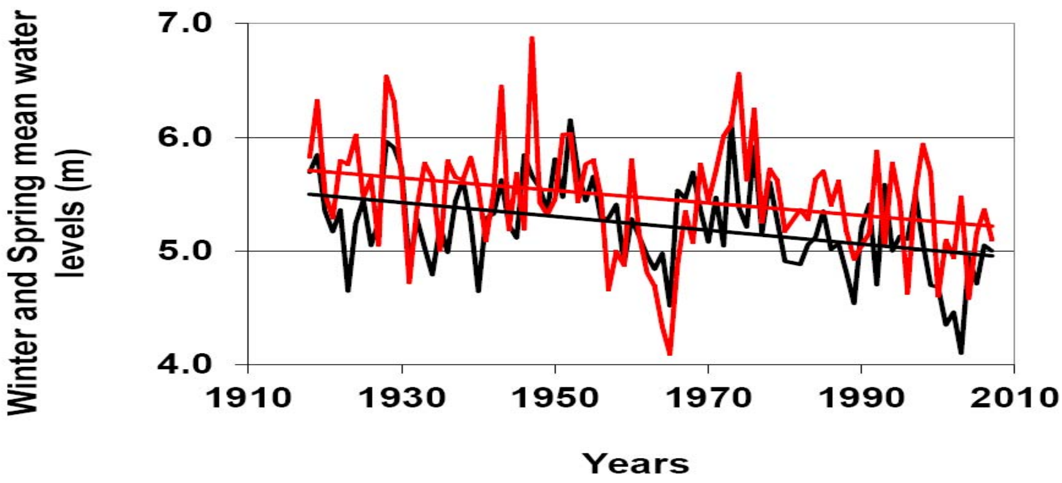

Fig.1. Interannual variability of winter and spring mean water levels of St-Lawrence River at Sorel station (1918-2007)

CONCLUSION

The study reveals a decrease in winter and spring seasonal water levels in the St. Lawrence River. The springtime decrease is likely due to the digging of the St. Lawrence Seaway, whereas the winter decrease would be linked to the way locks and dams are managed. According to climate model predictions (Boyer et al., 2010), there should be a significant decrease in springtime water levels in the St. Lawrence in the course of this century, resulting from a decrease in precipitation falling as snow and a large increase in evapotranspiration. The current climate warming trend should therefore enhance the decrease in springtime water levels which, in turn, could have severe morphological (e.g. renewed erosion in tributaries) and ecological (e.g. reduction in wetland/flood plain plant species diversity) consequences in Quebec.

LIST OF REFERENCES

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