Impact of Climate Change on Stream Water Temperature

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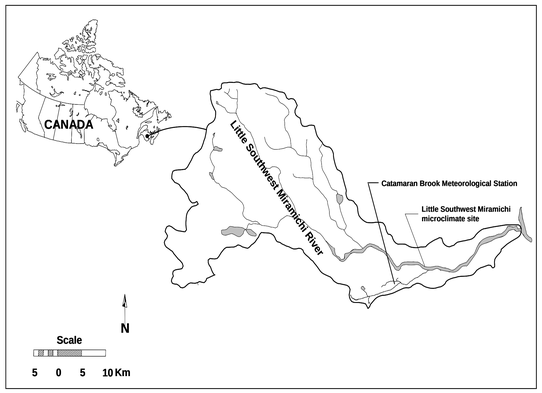
Abstract

The present study deals with the modelling of stream water temperatures under climate change scenarios by means of polynomial neural networks (PNN) to relate air and water temperatures in Little SW Miramichi (LSWM) River, New Brunswick. Future climate data were extracted from the Canadian Coupled General Climate Model (CGCM 3.1/T63) under the greenhouse emission scenarios B1 and A2 . The climate air temperatures were downscaled using delta change approach. The study predicts an increase in stream water temperature of between 2.1 ºC to 3.7 ºC, at the end of this century.

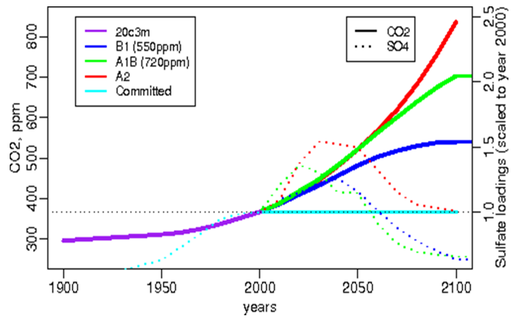
Study area

The study site is located on the Little Southwest Miramichi (LSWM) River, New Brunswick. Water temperature data have been collected at this site since 1992. The LSWM River is approximately 80 m in width with an average water depth of 0.55 m. The drainage basin of the LSWM River at the water temperature measurement site covers 1190 km^2. The data used in the present study were daily minimum, maximum and mean water temperatures calculated from hourly data (mean of 24 observations). Although the riparian vegetation is mature along the banks of the LSWM River, this river is nevertheless well exposed to meteorological conditions due to its relatively large width. Therefore, it can be considered as a wide and shallow river for modeling purposes. The forest along the LSWM has a canopy closure of less than 20%.



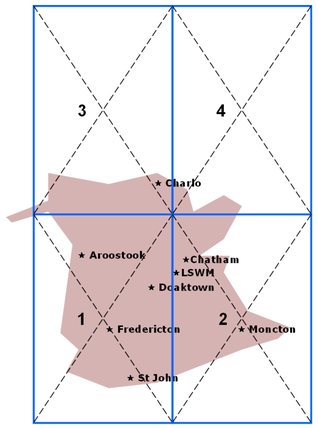
Climate model

Climate data were extracted from the Canadian Coupled Global Climate Model (CGCM3.1 / T63) under the green house gas emission scenarios 20C3M, B1 and A2 defined by the Intergovernmental Panel on Climate Change (IPCC).



Data from Doaktown, closest meteorological station to the LSWM River, were obtained from Environment Canada's National Climate Data Archive and used for climate change predictions.

Simulated daily minimum, mean and maximum air temperatures for the period 1970-2100 were obtained from CCCma, Canadian Centre for Climate Modelling and Analysis. The atmosphere model output is provided on a 128 x 64 Gaussian grid. The data are downscaled using delta change approach. The figure below shows the sub-region (4 grid boxes) occupied by New Brunswick.



Water temperature modelling

In a previous study (El-Jabi et al., 2012), stream water temperature and air temperature relationships were modeled by means of a regression and stochastic models and also by two intelligent algorithms: genetic programming and polynomial neural network (PNN). In all modeling approaches the root-mean-square error (RSME) was generally less than 2 ºC. The PNN model was used in this study because it was able to closely follow the behavior of stream water temperatures by providing simple equations which can be readily incorporated into any programming environment.

The following PNN model was used to predict minimum, mean and maximum stream temperatures:

$$\begin{Bmatrix} t \\ T(t), T(t-1), T(t-2) \\ T_{max}(t), T_{Max}(t-1), T_{max}(t-2) \\ T_{min}(t), T_{min}(t-1), T_{min}(t-2) \end{Bmatrix} \rightarrow \begin{Bmatrix} T_W^{min} \\ T_W \\ or \\ T_W^{max} \end{Bmatrix}$$

where T_W is the stream temperature (min, mean or max), t is the day of year (100 … 320, July 1=182), T, T_{max} *and* T_{min} are the mean, maximum and minimum air temperatures, respectively.

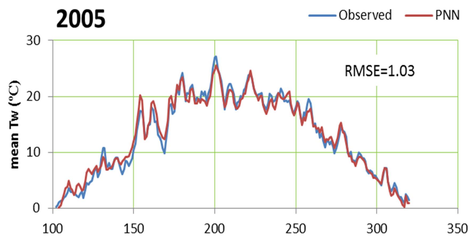
For example, the equation for the mean stream water temperature is :

$$T_W = 0.6502A + 0.4818B - 0.0212B^2 - 0.1652C + 0.0232C^2$$

$$A = -26.76 + 0.3358t - 0.0008t^2 + 0.2832T(t) + 0.0025T(t)^2 + 0.1417T(t-2) + 0.0073T(t)T(t-2)$$

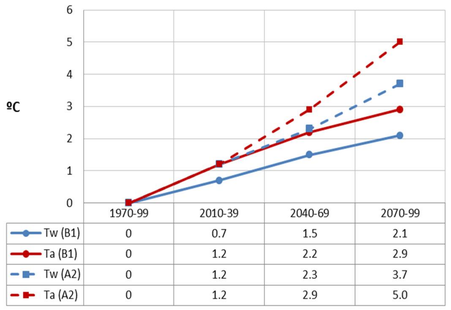
$$B = -33.96 + 0.4287t - 0.0010t^2 - 0.1391T_{min}(t) + 0.0010tT_{min}(t) + 0.4185T(t-1) - 0.0008tT(t-1) + 0.0022T_{min}(t)T(t-1) + 0.0070T(t-1)^2$$

$$C = -34.69 + 0.4412t - 0.0010t^2 + 0.0024T_{max}(t-1)^2 + 0.1463T(t-1) + 0.0002tT(t-1) + 0.0075T_{max}(t-1)T(t-1)$$



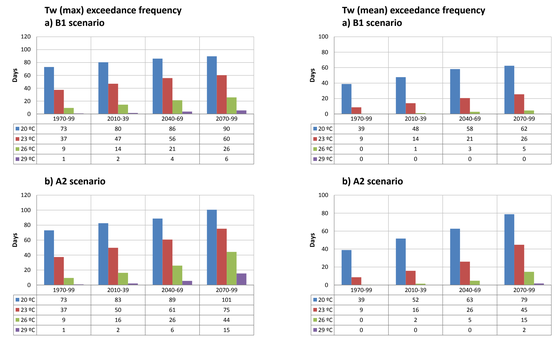
Observed and modeled mean stream water temperature values for year 2005 at LSWM River

Results



	1970-99	2010-39	2040-69	2070-99
Tw (B1)	0	0.7	1.5	2.1
Ta (B1)	0	1.2	2.2	2.9
Tw (A2)	0	1.2	2.3	3.7
Ta (A2)	0	1.2	2.9	5.0

Averaged air temperature increases at Doaktown and averaged stream water temperature increases at LSWM River under B1 & A2 scenarios



Mean annual exceedance frequencies of maximum and mean stream water temperatures for LSWM River using B1 and A2 scenarios

References

El-jabi, N., Turkkan, N. and Caissie, D. 2012. Stream water temperature modeling under climate change scenarios. Phase I: modeling stream water temperature and water / air temperature relationships. Report prepared for the New Brunswick Environmental Trust Fund (ETF) (PDF copy available at www.umoncton.ca/hydro)

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