Geophysical Research Abstracts
Vol. 14, EGU2012-6227, 2012
EGU General Assembly 2012

Determining the optimal spatial distribution of weather station networks for lumped and distributed hydrological modelling purposes using RCM datasets

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In many hydrological studies, the main limiting factor in model performance is low meteorological data quality and quantity. In some cases, like in Northern Canada and other sparsely populated areas, the meteorological records are practically inexistent. Installing weather stations becomes a necessity in these areas when water resource management becomes an issue, like when harnessing a river for hydropower generation for example. No guide exists as to where new stations should be located to optimize hydrological performance.

The objective of this study is to propose a new experimental and exploratory method for determining the optimal density of a weather station network when being used for long-term hydrological modelling. Data from the Canadian Regional Climate Model at 15km resolution (CRCM15) was used to create a virtual network of stations with long and complete series of meteorological data over the Toulnustouc River basin in central Québec. Three hydrological models were used in this study. Two are lumped (HSAMI and HMETS) while the last is distributed (Hydrotel). The weather stations to be fed to the models were selected in order to minimize the number of stations while maintaining the best hydrological performance possible. A multi-objective genetic algorithm was put in place to determine which stations were to be used, and by the same occasion, where the stations should be located.

It was shown that the number of stations making up the network on the Toulnustouc River basin should be at least two (2) but not higher than five (5), no matter what hydrological model is chosen. If the stations are positioned optimally, there is little to no gain to be made with a denser network. The optimization algorithm clearly identified that the right combinations of two or three stations can result in better hydrological performance than if a high density network was fed to the models. However, it was shown that a high number of stations will definitely reduce the variance related to the selection of the stations to be used.

The major conclusion of this study is that if weather stations are positioned at optimal locations, a very few number of them are required to model runoff with as good as or better performance than when a high density network is used.