The Relationship between Cyclone Characteristics and Annual Hydrological Resources over Québec

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1. Introduction

Cyclones can be considered as a significant component of the climate, because they are responsible for the most weather variations. They are also the origin of many extreme events. Variations of cyclone tracks have been related to large-scale circulation variability such as NAO and ENSO. In this article we will present the link between cyclone characteristics and the annual hydrological resources for one basin in Québec for the period 1960-1999.

2. Data Set

The diagnostic part of the study is performed using the NCEP 40-yr re-analysis data set (1960-1999) with a horizontal resolution of 2.5°, based on the orography, 1000-hPa geopotential, and 500-hPa wind. We also use the flow of natural water contribution from two hydrological basins of Québec (Outaouais and St-Maurice hereinafter grouped and noted OM).

3. Methodology

In order to find the main characteristics of the temporal and spatial cyclone distribution, we used two algorithms: the first permits to identify the cyclone centers and to organize them in tracks, Sinclair's algorithm (1994, 1997), while the second measures the occurrence, developed by Rosu (2005).

The cyclone tracks have been computed using the technique developed by Murray and Simmonds (1991), Sinclair (1994, 1997) and slightly improved by Rosu (2005). In Sinclair's algorithm, the tracking of the cyclones is undertaken with the 1000-hPa gradient-wind vorticity field, and the maxima are detected by comparing with the eight closest points. These maxima have to be larger than a selected threshold value. The tracking itself is performed at each 6 hours. To define the trajectory of a cyclone requires agreement between three characteristics of the cyclone center at the time *t* with the same three characteristics of the cyclone center at the next time. Thus, for each cyclone at the time *t*, a triple prediction is required, concerning the position, pressure and vorticity for the next point of the trajectory. The prediction is based on the history of the movement, pressure value, vorticity tendency and half of the value of the wind at 500hPa (Zwack, personal communication). When an agreement between the prediction and the analyses at the time t is satisfied, we consider that the next point of the trajectory is found.

In order to remove the weak perturbations and quasi-stationary centres, we imposed a set of conditions:

- ξ_g threshold is considered of 2.5×10^{-5};
- minimal value of track lifetime is one day;
- minimal track length is 1200 km.

Several statistical measurements were performed using the second part of the software: five density (cyclone density, tracks density, genesis density, lisys density and strong system density), five means (mean velocity, mean circulation, mean lifetime, mean speed and mean precipitable water), and also system density and mean velocity. All the statistics were directly calculated onto a sphere (we did not use projection), on a latitude-longitude grid, with the distance between the grid points of 2.5°x2.5°. In our calculation, we used statistics circles of 3° latitude centered on each grid point. Because the distance between the grid points is about 2.5° latitude and the statistics circle radius is 3° latitude, there is the risk to compute of many times the same cyclone which is located on the common area of the circles which are partial superimposed (for a detailed description of this algorithm, see Rosu 2005).

Because the most significant contribution of yearly water is recorded during the three months of March, April and May, we studied the entire year by taking in account these three months. The contribution of these three months during the 40 years of study was classified according to the standard deviation criteria. Thus, we obtain 12 years of strong hydraulicity (wet period, noted H "humide") and 17 years of weak hydraulicity (dry period, noted S "sec").

The present study shows two cyclone characteristics for seven months (NDJFMAM): cyclone density - the number of all the cyclone centers at the time of the analysis inside the circle of 3° latitude (number/month) - and track density - the number of all the trajectories that pass through the circle of 3° latitude (number/month). Our study was focused to find a relation between the water contribution observed during the three months (MAM) and the characteristics of the cyclones recorded during the period 1960-1999.

4. Results and analyses

Figures 1 and 2 show the Québec geographical distribution of cyclone system density and cyclone track density for 7-month cycle (from November to May) as a function of hydraulicity of two basins. The patterns and values are rather uniform, except over the area at the South-East of the region OM, where more frequent cyclones are present in periods of high hydraulicity.

The distribution of the monthly average of the cyclone number (fig. 3a) shows that there is a larger cyclone number for the wet period than for the dry period over the OM region, during the months MAM.

For the cyclone direction, fig. 3b reveals an increase of 11% during the wet period. Also, one notes significant increases in directions E and SE. Thus, there is an increase of cyclones coming from the Great Lakes and the James Bay during the wet years for the cyclones.

5. Conclusions

For the study period over the OM region, we noted an increase of 20% of the cyclones and trajectories number for the wet period; the maximum of densities are recorded for the areas located over or in the vicinity of the Appalachian Mountains. The position of this maximum and the favoured displacement of the cyclones towards the North-East result in increased precipitations in the OM region during the wet years

Concerning the cyclone direction for the MAM, a strong increase of the number of cyclones moving towards the East and North-East is noted during the wet period.

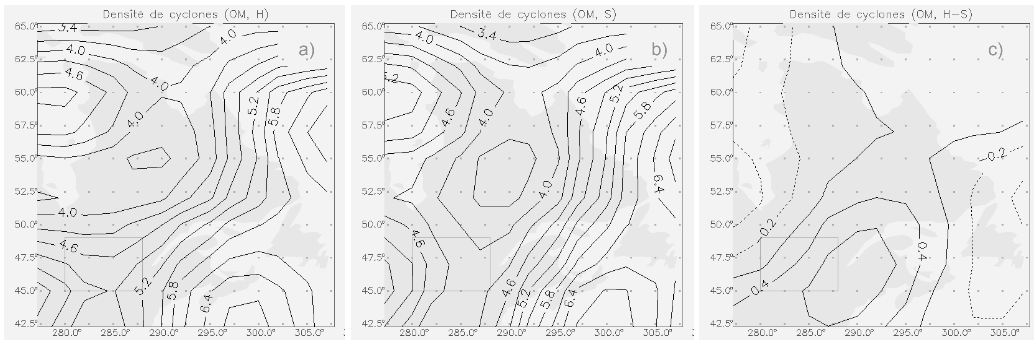

Figure 1: Cyclone system density during period (a) of strong hydraulicity (H), (b) of weak hydraulicity (S) and (c) the difference (solid lines for positive differences and dashed lines for negative differences). Contour interval every 0.2 centers per 3° latitude circle per month.

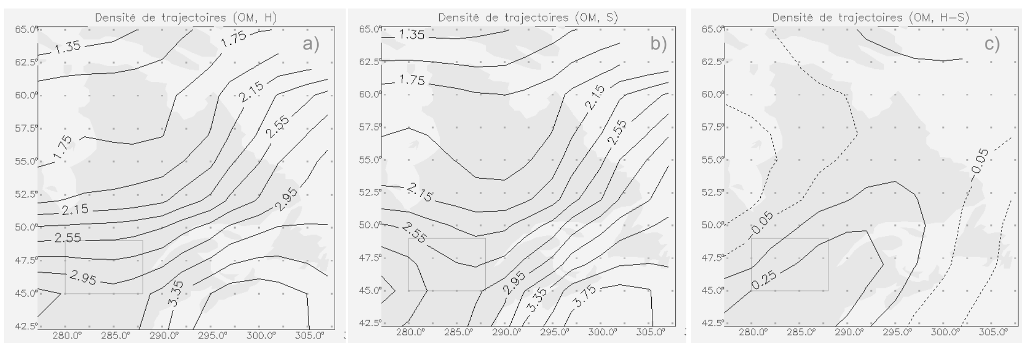

Figure 2: Cyclone track density during period (a) of strong hydraulicity (H), (b) of weak hydraulicity (S) and (c) the difference (solid lines for positive differences and dashed lines for negative differences). Contour interval every 0.15 tracks per 3° latitude circle per month.

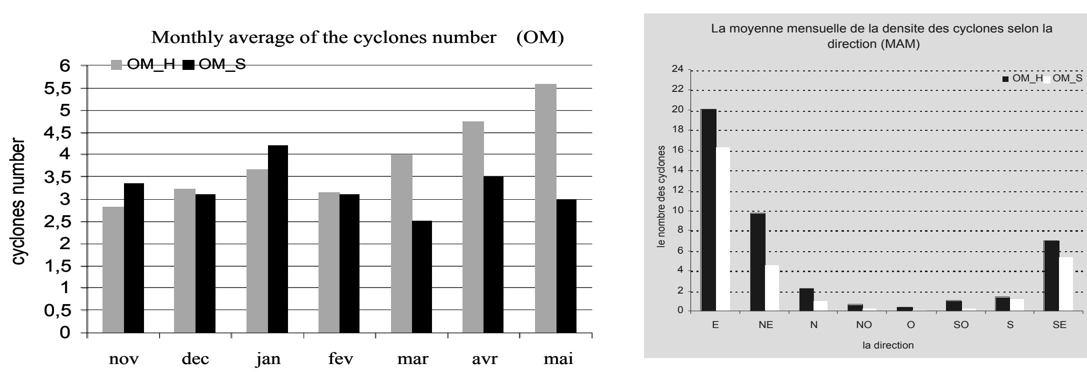

Figure 3: Monthly average of the cyclone number observed about the basins OM during the strong (H) and weak (S) hydraulicity periods (a), and monthly average of the cyclone system density function of cyclone direction (b).

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