# Interaction between atmosphere and ocean-ice regional models over the Gulf of St-Lawrence area (Canada)

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## 1. Introduction

A numerical experiment using the Canadian Regional Climate Model developed at the "Université du Québec à Montréal" (CRCM, Caya and Laprise 1999) and the Gulf of St-Lawrence ocean model developed at the "Institut Maurice-Lamontagne" (GOM, Saucier *et al*. 2001) investigates the sensitivity of the models to each other with a series of simulations over Eastern Canada. The sensitivity of these models has already been investigated for short simulation by Gachon *et al*. (2001). However, we need to understand the interactions between the atmosphere, the ocean and the sea-ice over the Gulf of St. Lawrence (GSL) using these two models on a longer time scale. Furthermore, we wish to understand the role of these interactions in the present-day climate of Eastern Canada to develop a modelling strategy to perform regional climate change scenario for this area.

## 2. Experimental framework

A series of atmospheric and oceanic simulations are performed iteratively. The CRCM and GOM were run separately and alternatively over a fixed period of 5 months, using variables from the other model to supply the needed forcing fields. Each model computes its own surface budget of momentum, heat and freshwater at the interface between the atmosphere and the ocean-ice system from the exchanged variables. The study period is from November 1$^{st}$, 1989 to March 31$^{st}$, 1990, including a spinup of 1 month.

The computational domain of the CRCM is centered over the GSL (Fig. 1). It contains 99 by 99 grid points in the horizontal with a grid spacing of 30 km (true at 60˚N) on a polar stereographic projection. There are 30 levels in the vertical between 131 m and 31 953 m. The timestep is 10 minutes. The lateral boundary conditions are obtained from the NCEP (National Center for Environmental Predictions) analyses. The computational domain of GOM extends from the Strait of Cabot to Montréal and at the head of the Saguenay Fjord. The horizontal resolution is 5 km on a rotated-Mercator projection. The ocean is layered in the vertical with a uniform resolution of 5 m down to 300 m depth and 10 m below 300 m.

A first simulation begins the iteration with the CRCM (CRCM1) taking observations from the AMIP II database (Atmospheric Models Intercomparison Project, Gates 1992) to provide the initial oceanic forcing fields. The AMIP data includes the sea-surface temperature (SST) and sea-ice fraction (SIF) with a spatial resolution of 1 degree. The atmospheric fields of CRCM1 (incident solar radiation at the surface, cloud cover, precipitation, 10-m wind, 2-m temperature and humidity) are archived every 6 hours and are used to prescribed the atmospheric state for a first oceanic simulation with GOM (GOM1) over the same 5-month period. The once-daily archived results of GOM1 (SST, SIF and sea-ice thickness) are used to repeat the atmospheric run (CRCM2); the AMIP data are used to supply the oceanic state outside the GSL. This second atmospheric simulation is used to repeat the oceanic simulation (GOM2) and so on. The process is iterated 3 times to study the evolution of the CRCM and GOM solutions when the atmospheric or oceanic fields are updated from the previous run.

## 3. Results

The experiments show that GOM can provide high-resolution oceanic forcing variables compared with the interpolated AMIP data. However, the CRCM is rather insensitive to differences in the oceanic fields during our study period. For example, as a result of a 50% decrease in the sea-ice cover in the GSL from the interpolated AMIP to the GOM1 data in December 1989, the difference in monthly mean temperature at 975 hPa (CRCM2 minus CRCM1) is at most 2.7˚C locally along the West Coast of Newfoundland (Fig. 1a). Furthermore, the difference is restricted to the low level of the atmosphere and vanishes at 900 hPa. However, the warming of the air above the GSL is responsible for further reduction in the sea-ice and an increase in the ocean surface circulation from GOM1 to GOM2. On Fig. 1b, the monthly mean sea-ice extends over a large part of the GSL in GOM1, but it is restricted to the western half of the GSL in GOM2. The results have also shown that the sea-ice fraction is reduced by 10% to 15% and thinner in GOM2, compared with that in GOM1 (not shown). On Fig. 2, the monthly mean surface currents for December 1989 show relatively large differences from GOM1 to GOM2. In particular, the Gaspé current flows along the Gaspé Peninsula in GOM1 (Fig. 2a), while it is detached from the coast and extends further east in GOM2 (Fig. 2b). This experiment indicates that the position of the Gaspé current follows an area of slightly warmer, less stable atmospheric conditions and stronger winds, in relation with the sea-ice distribution. The warming trend has continued into the third iteration, but with reduced amplitude. The 975-hPa air temperature difference (CRCM3 minus CRCM2) is smaller, reaching 1.8˚C south of Anticosti Island (not shown). On Fig. 1b, the sea-ice cover in GOM3 is further reduced, with the position of the edge approximately 30 km west of that in GOM2. Two additional iterations have been done for December 1989 to verify and confirm the convergence of the solutions for both, the CRCM and GOM. The results show that the differences in various fields become smaller as the number of iterations increases.

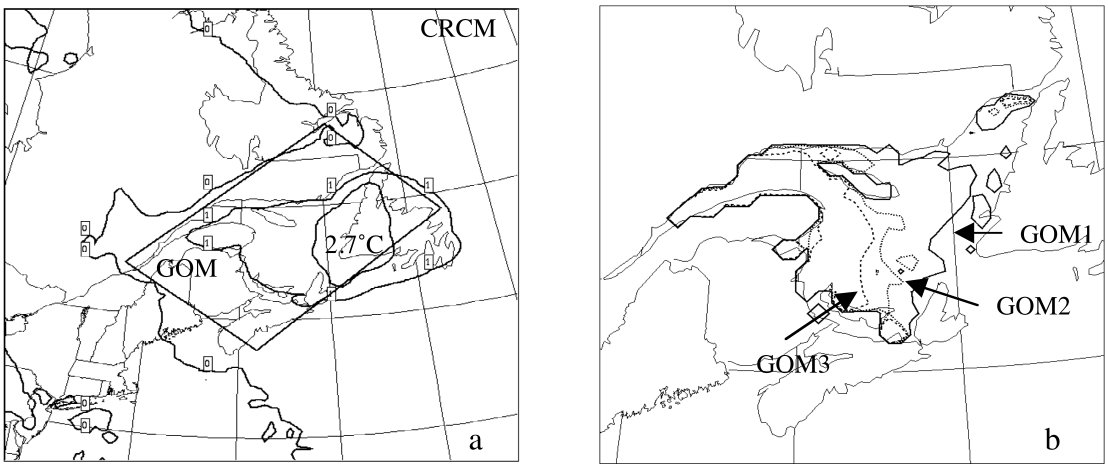


Figure 1. (a) Model domain of CRCM, including GOM's domain within the rectangle. Contours are the difference of monthly mean 975 hPa temperatures for December 1989 every 1˚C (CRCM2 minus CRCM1). (b) Monthly mean sea-ice fraction (%) for December 1989 from GOM1 (solid line), GOM2 (dotted line) and GOM3 (dashed line).

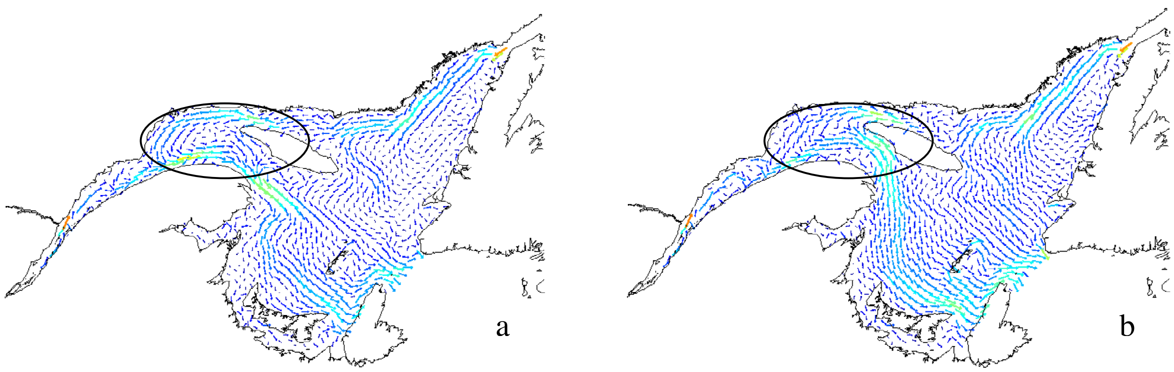


Figure 2. Monthly mean surface current (m $s^{-1}$) for December 1989 from (a) GOM1 and from (b) GOM2. The ellipses highlight the Gaspé Current.

## 4. Concluding remarks

The results of this experiment show that, on a monthly or longer time scale, the CRCM is not very sensitive to the oceanic fields from GOM, except locally in the Gulf area and near the surface. However, GOM is relatively sensitive to small differences in the atmospheric forcing from the CRCM. An important result is the convergence of the solutions, indicating that both models are reaching equilibrium with respect to each other. The sensitivity of the models to each other was investigated for a winter season. However, we need to continue the study over an annual cycle.

**References**

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