Evaluation of summer-time near-surface temperature and wind fields over Hudson Bay in a regional atmospheric model

Philippe Gachon[1], François J. Saucier[1] and René Laprise[2]
[1]*Maurice Lamontagne Institute, Ocean Sciences Branch,*
Department of Fisheries and Oceans,
850 route de la Mer, Mont-Joli, Qc, Canada G5H 3Z4
[2] *Department of Earth & Atmospheric Sciences, University of Québec at Montréal, Montréal, Qc, Canada*
e-mail : gachonp@dfo-mpo.gc.ca

The Hudson Bay (HB) climate system is dominated by the presence of a seasonal sea ice cover over 8 months per year. This has a considerable effect on the regional climate (i.e. on the mesoscale atmospheric circulation, e.g., Gachon, 1999, on precipitation variability and regime, continental permafrost, snow cover and the annual hydrological cycle) and biota (e.g. Gough and Wolfe, 2001). The relatively short ice-free period between the end of July early November is important in controlling the mixed-layer heat storage and the formation of sea ice in the fall.

In summertime, the sea surface temperature (SST) over the most part of HB is considerably cooler (typically from 1°C in the north to 10°C in the south) than the surrounding land surface temperature. The low-level air temperature is cooled by heat intake over the Bay. This produces a shallow low-level inversion that increases the near surface atmospheric stability over sea water. This has effects on humidity, temperature and wind profiles (see Figs 2a and 2b, respectively), as well as low-level clouds and radiation. Those in turn control the seasonal oceanic heating of the mixed layer.

The coupling of the Canadian Regional Climate atmospheric Model (CRCM described in Caya and Laprise, 1999) to a Hudson Bay ocean model (as described in Senneville et al., this volume) requires that each one reproduce vertical fluxes correctly. Herein we evaluate low-level temperature and wind fields as simulated by the CRCM for August 1996 (with a 25-km horizontal resolution and 40 layers in the vertical). The CRCM is driven by reanalyses from the Canadian forecast model (100-km resolution global grid archived every 6 hours) using daily observed SST and sea ice cover concentration (still present in western HB at the beginning of August, see Fig. 1). The land surface temperature is initialised on August 1st 1996 from the reanalyses. We examine the differences in screen-level temperature and anemometer wind speed between the high resolution reanalyses from the regional version of Canadian forecast model at a 35-km resolution (Mailhot et al., 1997) and the CRCM results over HB. The screen-level temperature is also compared with the meteorological observations at four stations over land near the eastern and northern HB shores (i.e. La Grande Rivière, Kuujjuarapik, Inukjuak, and Kuujjuaq, see Fig. 1). The screen-level temperature calculated by the CRCM is diagnosed from the surface temperature and that at the lowest model level as described in McFarlane et al. (1992). The wind at the 10 m anemometer level in the CRCM is diagnosed from the lowest prognostic level for momentum and using a bulk Richardson number criteria for stability function, such as the screen-level temperature (e.g. Boer et al., 1984; McFarlane et al., 1992).

As shown in Fig. 2a, the temperature above HB differs from the reanalysis and the CRCM results with large differences during the first six days of the month and at several times thereafter. During these periods, the CRCM is cooler than the reanalyses by 3 to 7°C with a strong dependence to the cold SST, which in turn reduces the variability of the CRCM low-level air temperature (see the SST and CRCM time series in Fig. 2a). Recall that both the reanalyses and the CRCM use the same SST (updated every day). As shown also in the wind speed (Fig. 2b), the CRCM simulates periods of calm (no winds) conditions compared to the reanalyses, but the strong wind events are reproduced similarly. The calm periods are associated with colder temperature in the CRCM (Fig. 2a). This is a result of enhanced near surface stability in the CRCM. These periods of calm conditions or underestimated wind speed in atmospheric models have also been found over other cold oceanic surface such as the Gulf of St. Lawrence in summer. This result points to the importance of future work on the boundary layer treatments in the CRCM, and the criteria used for calculating the wind at anemometer level. As suggested by Taylor (2001), the performance of bulk formulation as used in CRCM for simulating the near-surface turbulence fluxes, needs to be better established for stable conditions. This would require new data on vertical profiles over the HB.

Along the eastern shore, the CRCM results can be validated from the meteorological stations. The temperature evolution is relatively well reproduced (Fig. 3), but with a higher RMS error than the reanalyses (Table 1). As over HB, the temperature temporal variability is generally underestimated in the CRCM except for Inukjuak station (as shown in Table 1). At this station, the CRCM is more systematically warmer than at other stations (Fig. 3). This bias can in part be attributed to the use of a one layer only land surface sheme, as suggested in the previous work of Verseghy (1996) and the recent study over northern Québec of Frigon et al. (this volume). As for over sea, the analysis of a more complete set of terrestrial stations around the Bay with the CRCM results should improve the evaluation of the model, in particular in the western part of the Bay upstream of the HB influence.

Our study is at present too limited in scope to be definitive. However, it suggests that much work is required in the CRCM for estimating the screen-level fields and the surface exchanges processes over cold surfaces such as HB in summertime. This is true not only for future on-line coupling but also for off-line forcing of the ocean model as the mixed layer properties of HB are sensitive to the accuracy of atmospheric fields in summer months, as suggested in the preliminary studies of Senneville et al. (this volume).

References

Boer, G.J., N.A. McFarlane, R. Laprise, J.D. Henderson, and J.P. Blanchet. 1984 : The Canadian climate centre spectral atmospheric general circulation model. *Atmos. Ocean*, **22**, 397-429.

Caya, D., and R. Laprise. 1999. A semi-implicit semi-lagrangian regional climate model : The Canadian RCM. *Mon. Wea. Rev*., **127** : 341-362.

Gachon, P. 1999 : Effets de la distribution de la glace marine sur le développement des dépressions à méso-échelle et sur le climat régional, PhD's Thesis, University of Québec at Montréal (UQAM), Montréal (Québec, Canada), 352 p.

Gough, W.A., and E. Wolfe. 2001. Climate change scenarios for Hudson Bay, Canada, from General Circulation Models. *Arctic*, **54**, 2, 142-148.

Mailhot, J., R. Sarrazin, B. Bilodeau, N. Brunet, and G.

Pellerin. 1997. Development of the 35-km version of the Canadian regional forecast system. *Atmos.-Ocean*, **35**, 1-28.

McFarlane, N.A., G.J. Boer, J.P. Blanchet, and M. Lazare. 1992 : The Canadian climate centre second-generation general circulation model and its equilibrium climate. *J. Climate*, **5**, 1013-1044.

Taylor, P.K., Ed.. 2001. Intercomparison and validation of ocean-atmosphere energy flux fields. Joint WCRP/SCOR Working Group on Air-Sea Fluxes Final Rep., WCRP-112, WMO/TD-No, **1036**, 306 pp.

Verseghy, D.L.. 1996 : Local climates simulated by two generations of Canadian GCM land surface schemes. *Atmos.-Ocean*, **34(3)**, 435-456.

Fig. 1. Land-sea-ice mask used in the CRCM valid on August 1st 1996 (black is the land, light grey the open ocean, and white the sea ice).

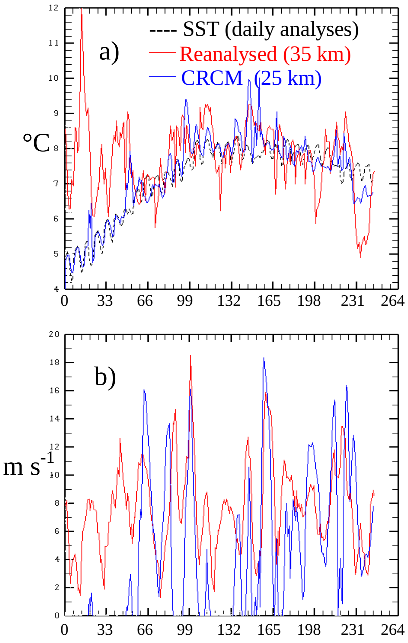

Fig. 2. Temporal evolution (every 3 hours) of (a) SST (daily analyses in dashed line) and air temperature (at 2 m, in °C) and (b) wind speed (at 10 m, in m s^{-1}) over HB for reanalysed (35-km grid) and CRCM values. X-axis corresponds to the 8 times daily archived fields (1-31 August 1996).

Temperature (°C)	**Observed** (ST)	**Reanalysed (35 km)**	**CRCM (25 km)**
La Grande Rivière 53.63°N-77.7°W	6.46	5.89 **1.95**	5.21 ST **3.71 RMS**
Kuujjuarapik 55.28°N-77.77°W	5.92	4.84 **2.65**	3.42 ST **4.15 RMS**
Inukjuak 58.47°N-78.08°W	2.79	3.09 **1.47**	3.79 ST **3.74 RMS**
Kuujjuaq 58.1°N-68.42°W	5.29	5.48 **1.99**	4.48 ST **4.13 RMS**

Table 1. Standard deviation (ST) and Root Mean Square error (RMS, between observed and reanalysed, and observed and modeled) during August 1996 for temperature at terrestrial stations (see Fig. 1).

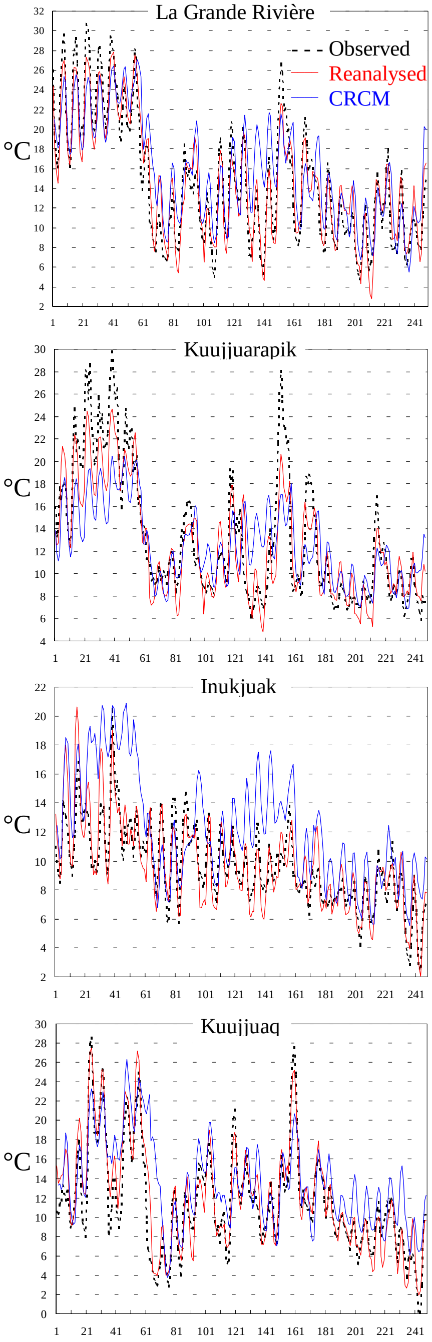

Fig. 3. As Fig. 2a but for the temporal evolution of temperature at terrestrial stations (shown in Fig. 1).