Development of a Coupled Ice-Ocean Model of Hudson Bay

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The seasonal cycle of water masses and sea ice production and circulation in the Hudson Bay basin is examined using a baroclinic coastal ice-ocean model including a level 2.5 turbulent kinetic energy equation. The resolution of this model is 10 km in the horizontal and 10 to 50 m in the vertical. The time step is 5 minutes. The domain includes Foxe Basin, Hudson Strait, and James Bay. The model is driven from tidal, atmospheric, hydrologic and oceanic forcing, as done for the Gulf of St. Lawrence in Saucier et al. (2002). The aim is to first reproduce the main features (e.g., transports, heat, freshwater and sea-ice seasonal cycles) using 3-hourly atmospheric reanalyses, and then to couple this model into the Canadian Regional Climate Model (CRCM) (Caya and Laprise, 1999) and into the Global Environmental Multiscale (GEM) model (Coté et al., 1997) for improving and downscaling climate change scenarios and the Canadian operational weather forecast, respectively.

A model simulation over 1996-97, driven by the CMC Regional Finite Element (RFE) and GEM reanalyses, is verified against climatological data. The model is forced at the mouth of Hudson Strait from 10 harmonic components obtained from Matsumoto et al. (2000). Figure 1 shows the modelled co-phase and co-amplitude chart for the M2 tidal harmonic. The mean relative error in amplitude is 9% and the RMS phase error is 20^{o} for 9 tide gauge shore stations around the domain. The mean surface currents (Figure 2) reproduce the general pattern reported from observations. Freshwater from major tributaries around the Bay form a coastal current exiting through Hudson Strait and partly re-circulating through the Bay. The sea-ice cover growth during fall 1996 is presented in Figure 3 with the evolution of the 5 cm ice thickness contour at 10 day intervals over the period extending between November 18 and December 28. The presence of higher values for thickness and concentration of sea-ice in the southern part of Hudson Bay near the end of the simulation in July is also well reproduced by the model (not shown). Figure 4 shows the domain-averaged salinity, temperature, and turbulent kinetic energy (TKE) over the simulation period. The salinity shows the effect of salt rejection associated with sea-ice growth, followed by a reduction associated with the late spring runoff. The temperature shows the deepening of the surface mixed-layer in fall, with wind-driven mixing reaching about 100 m depth. Finally the seasonal cycle of TKE shows a strong neap to spring tidal cycle near the bottom of Hudson Bay, and little wind-induced TKE under sea-ice. These results show a consistent seasonal cycle in atmosphere-ocean exchanges, mixing, and the formation and circulation of water masses and sea ice.

The modelled delay in freeze-up dates in the fall is related to the accuracy of the low-level atmospheric fields (e.g., lower winds and higher temperature) which leads to relatively large biases in the mixed-layer heat cycle and sea ice production. These results point to the importance of improving the atmospheric model as it is the foremost limiting factor in the accuracy of ocean solutions. Once a balanced seasonal cycle is obtained, the model can be run over a period of several years to a decade in order to examine climate variability and changes associated with the atmospheric and hydrological forcing.

References:

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Results :

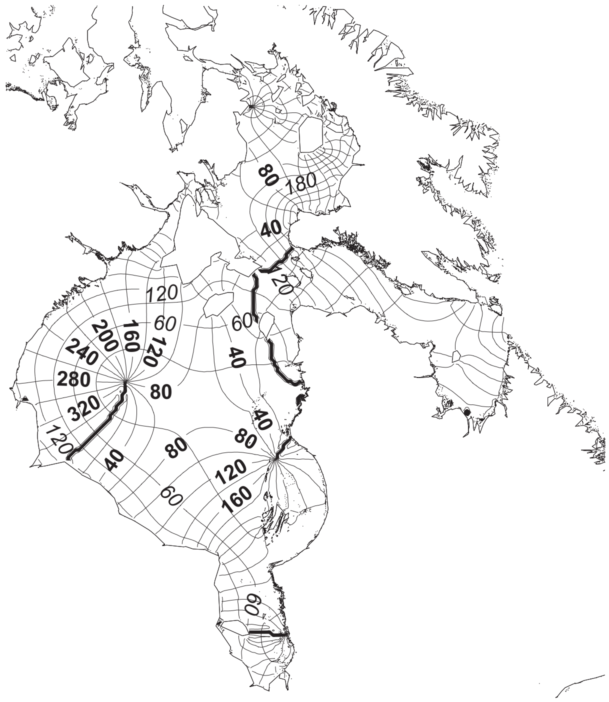

Figure 1: Tidal chart of M2 component : Co-amplitude (bold) and co-phase (italic).

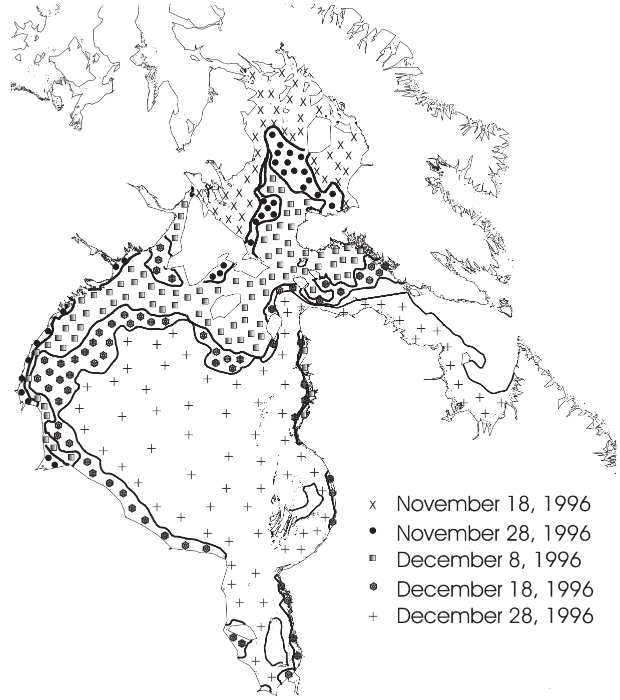

Figure 3: Date of sea-ice formation over 5cm thickness

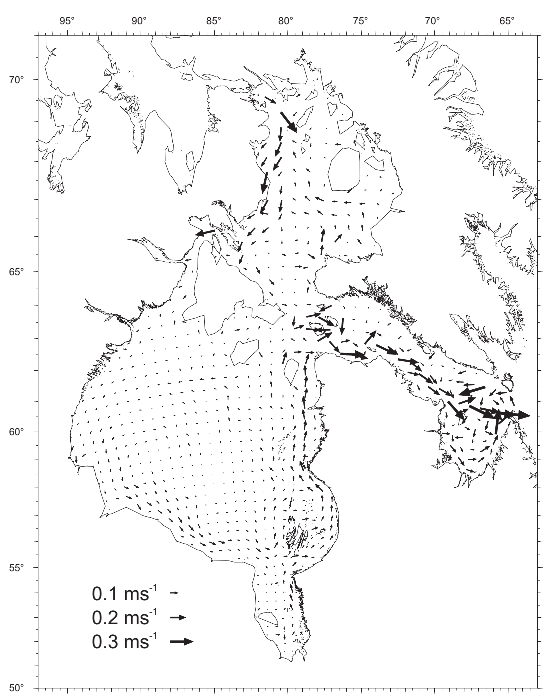

Figure 2: Yearly mean surface current (surface 10m)

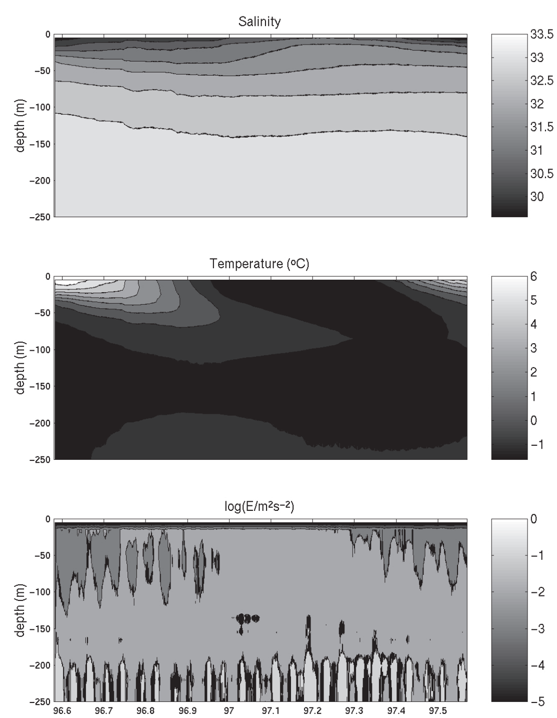

Figure 4: Domain-averaged salinity, temperature, and turbulent kinetic energy