What controls the dispersion of riverine freshwater in Hudson Bay during the summer?

St-Laurent, P. (1)
F. Straneo (2)
J.-F. Dumais (1)
D.G. Barber (3)

Arctic Change 2008

ArcticNet (3)
UQAR ISMER (1)
Woods Hole Oceanographic Institution 1930 (2)

1–Introduction

Recent studies report significant changes in the river discharge of the Arctic and sub-Arctic basins [1,2]. Rivers often represent a key component of the freshwater cycle in shelf seas [3], and such long-term changes in river discharge have the potential to alter the climate of the seas [4]. Similar changes can arise from the alteration of the seasonal river discharge through hydroelectric projects [5].

While long-term changes in river discharge may modify the climate of these seas, they can also influence their biogeochemical content. River transport is often associated with terrigenous material [6], pollutants [7] and nutrients, these having various effects upon marine life. In many cases the pathway and residence time of these substances is poorly known.

These questions are particularly appropriate for Hudson Bay, a large sub-Arctic sea with an important freshwater input [1]. Its river discharge has decreased by 13% over the last 35 years [2], and hydroelectric developments are underway. What processes control the spreading of river water, and its chemical load, in Hudson Bay?

2–Approach

We gain insight on the processes controlling the spreading of riverine waters by performing a numerical experiment. Passive tracers are injected at the mouth of several key rivers in early summer, and the tracer patches are tracked over the ice-free period (1 Aug.–1 Dec.). The numerical model makes use of realistic forcing for rivers, tides, ocean and atmosphere [8], and it reproduces the main features of the circulation.

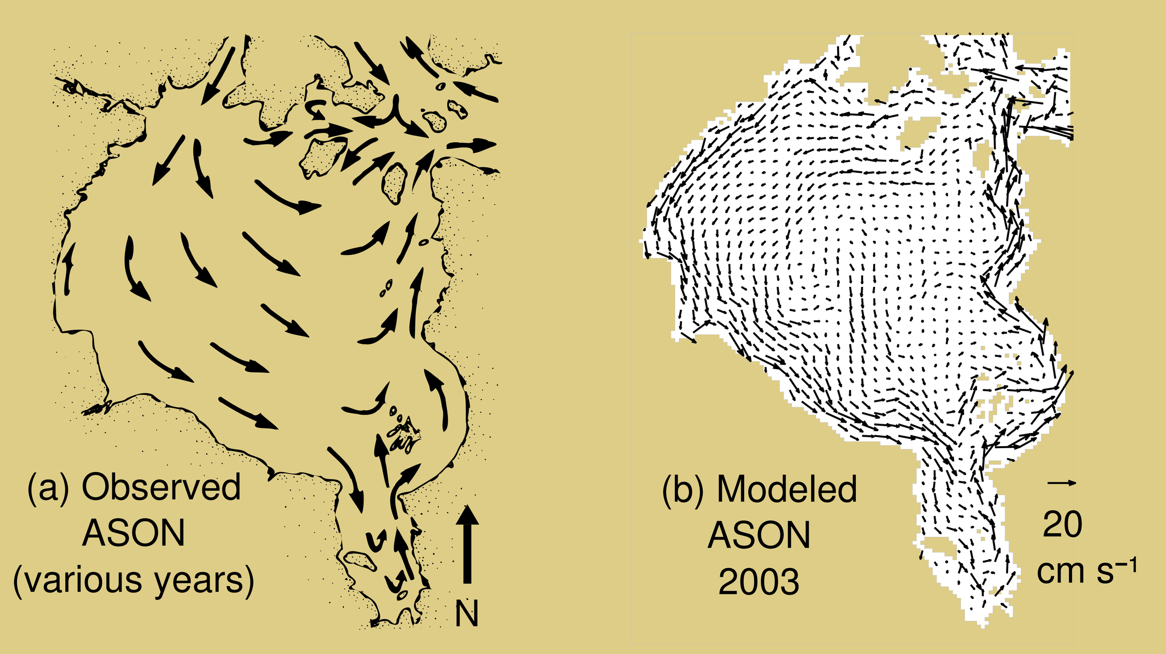

Fig. 1. Near-surface circulation pattern derived from (a) observations [9] and (b) the simulation.

[1] Lammers et al., 2001, p. 3321-3334, J. Geophys. Res.
[2] Déry et al., 2005, p. 2540-2557, J. Clim.
[3] Prinsenberg, 1984, p. 191-200, Cont. Shelf Res.
[4] Prinsenberg, 1983, p. 418-430, Atmos.-Ocean.
[5] Prinsenberg, 1980, p. 1101-1110, CJFAS.
[6] Granskog et al., 2007, p. 2032-2050, Cont. Shelf Res.
[7] Mailman et al., 2006, p. 224-235, Sci. Tot. Env.
[8] Saucier et al., 2004, p. 303-326, Clim. Dyn.
[9] Wang, et al., 1994, p. 2496-2514, JPO.
[10] Taylor, 1954, p. 446-468, Proc. Roy. Soc.
[11] Csanady, 1980, Elsevier.

3–Circulation of the river waters

Four rivers were chosen according to their relatively large discharge and hydroelectric potential. The river patches generally describe a cyclonic motion, and they are mostly confined to the boundary region. The mean velocity of the patches increases from 5 cm s^{-1} along the western shores to 8 cm s^{-1} along the eastern shores.

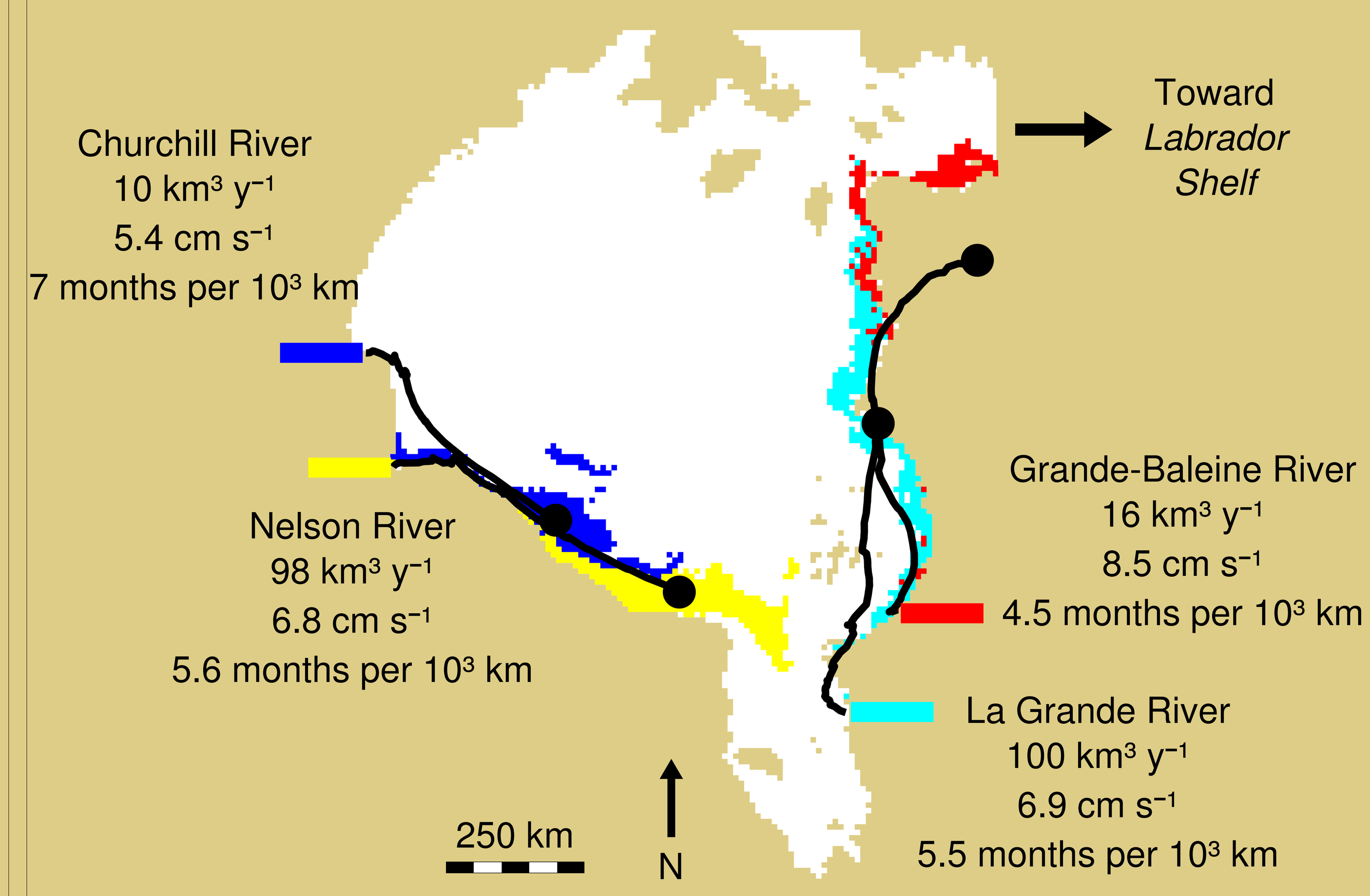

Fig. 2. Relative extent of the river patches at the end of the ice-free period (1 Dec.). The thick lines show the trajectory of the patches over this period. Numbers indicate the mean river discharge, the mean velocity of the river patch, and the corresponding travel time for a 1000 km distance.

4–The spread of a river patch

The river patches typically grow into extended plumes in the along-flow direction, this feature being mainly caused by the sheared advection [e.g. 10,11]. The enhanced spreading in the along-flow direction contributes to the mixing of the individual river waters inside the fresh boundary flow.

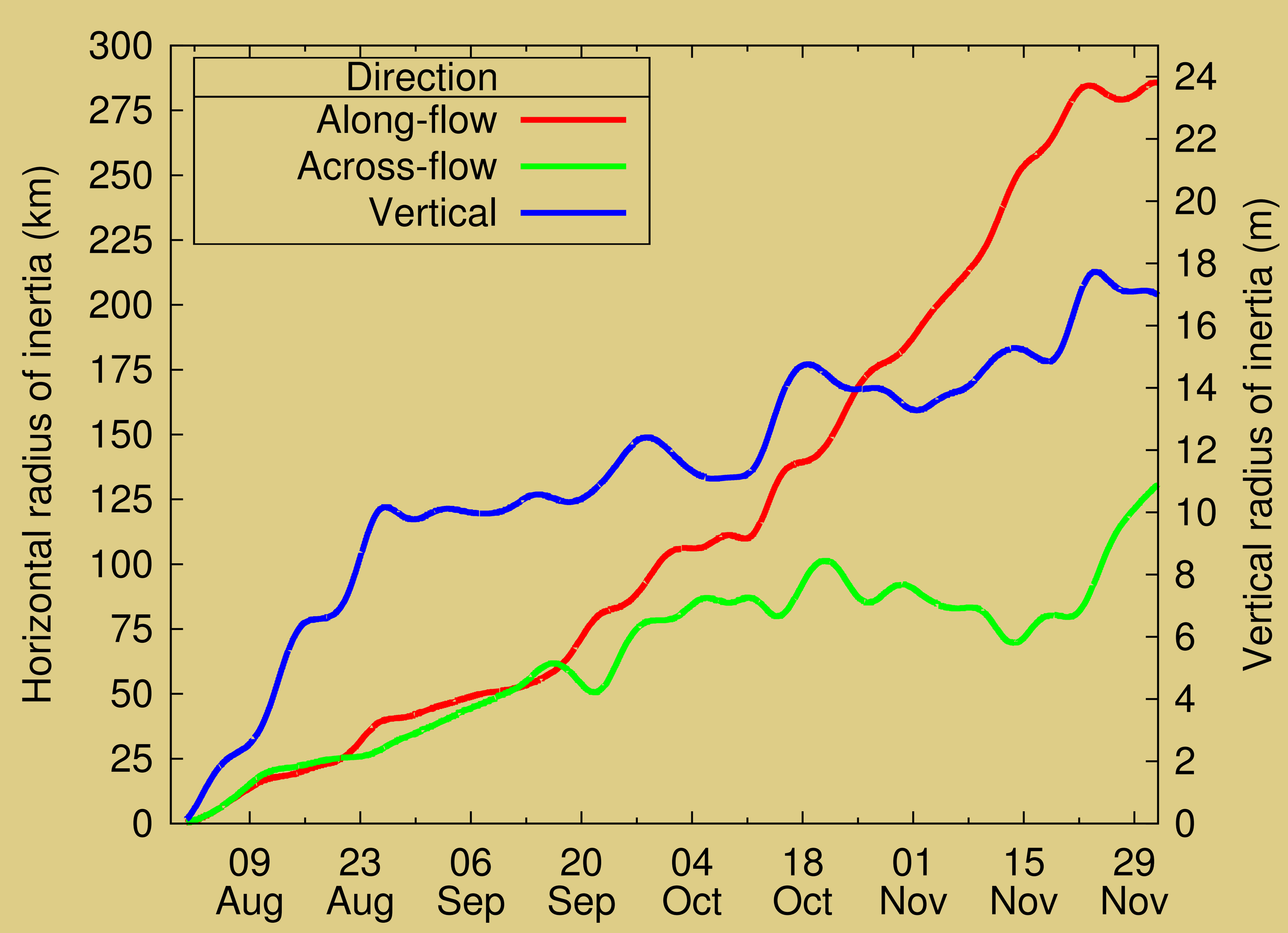

Fig. 3. Spread of the La Grande River patch along three directions and over the ice-free period.

5–Wind-driven deepening of the river waters

Intense wind events play an important role in speeding up the advective flow and spreading the river patches along the vertical direction. The summer wind stress [9] is aligned so that both downwelling and wind-driven mixing are likely to contribute to the deepening of the river waters.

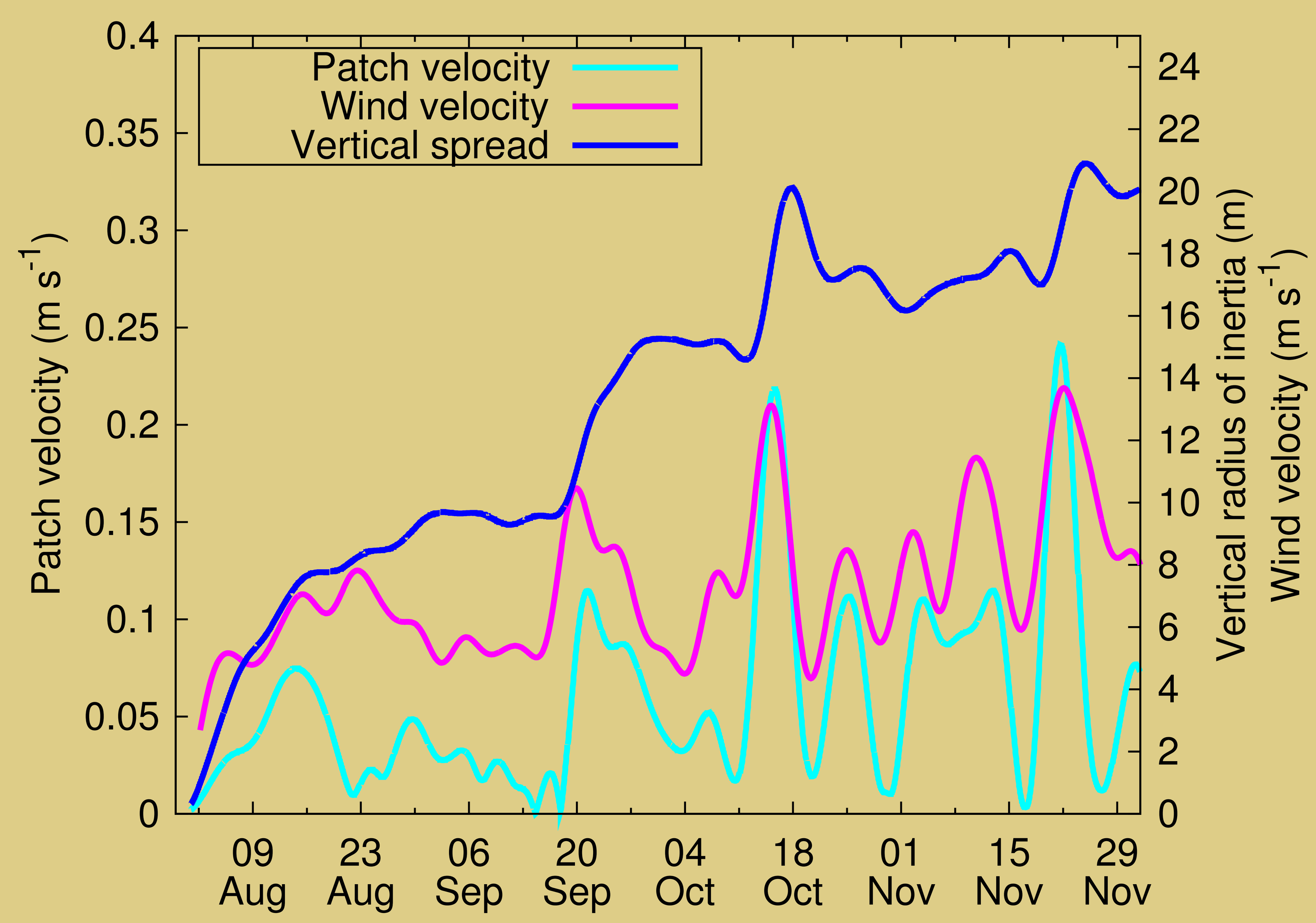

Fig. 4. Velocity and vertical spread for the Nelson River patch. The local wind velocity is superimposed.

6–Conclusions

- River waters are generally confined to the boundary region and their velocity increases as they approach the mouth of Hudson Bay.
- The sheared boundary flow is effective at diluting and mixing the individual river waters inside the fresh boundary region.
- Intense wind events play an important role in spreading the river patches along the vertical direction, and speeding up the advective flow. Such increase in the advective flow means a lower travel (residence) time for the riverine waters inside the system.

This study is a part of the ArcticNet-FW project investigating the budget and residence time of Hudson Bay's fresh waters, and their role in the estuarine circulation of the basin.

Acknowledgements
We thank S.J. Lentz for helpful discussion, S. Senneville and J. Caveen for technical support. This work is a contribution to the ArcticNet program, which is gratefully thanked for financial support.