Hudson Bay Modeling

Identifying gaps in our current knowledge

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Outline

- Non-exhaustive review of recent modeling work
  - The freshwater-marine coupling cycle

- Discussion
  - Model strength and limitations
  - Where to go from here?
The HBS numerical model

Finite difference hydrostatic primitive equations of geophysical fluid dynamics are solved numerically on a 3D grid with geopotential vertical coordinates (z-levels)

\[ \Delta x = 10 \text{ km} \]
\[ \Delta z = 10-50 \text{ m} \]
\[ \Delta t = 300 \text{ s} \]
Coupled ice-ocean modeling

Atmospheric forcing

Run-offs

OBC: Hydrography and tides
IC: Spin-up from climatology
The general circulation is cyclonic.

River waters transported by a buoyancy-driven coastal current.

Under-ice friction slows down surface currents.
Baroclinic radius of deformation $\sim O(5) \text{ km}$

St-Laurent et al. (2011)
River influence

St-Laurent et al. (2011)
Freshwater exchanges and export

St-Laurent et al. (2011)
Freshwater residency time

The same year (2004) is run many times.

St-Laurent et al. (2011)
Conceptual model

St-Laurent et al. (In press)
Conceptual model results

![Graph showing freshwater flux relative to 33 psu (mSv) from September 2004 to May 2007, with peaks in 2004, 2005, and 2006. The map on the right indicates the location of the observation point (Observ.) and the mode direction.]
The wind-driven accumulation / release mechanism controls the export of freshwater through Hudson Strait more than rivers do.
Sea ice

Data from ice charts (Canadian Ice Service)

Saucier et al. (2004)
Sea ice concentration and volume

Saucier et al. (2004)

Coastal polynyas

Not present in ice charts
Too close to boundaries
Tides

Tides are forced at the entrance of Hudson Strait and propagate cyclonically in the HBS.

They are responsible for the formation of sensible heat polynyas in Belcher Islands.

Saucier et al. (2004)
Tides

The Hudson Bay / Hudson Bay / Labrador Sea System is where tidal dissipation is highest in the world (Egbert et al. 2002).

Under-ice friction further dissipates tidal energy, modifies its phase, reduces surface currents, and affect the density field through mixing.

The interannual and climatic scale

Posters:

S. Senneville and S. St-Onge-Drouin, *Modeling future sea ice conditions in Hudson Bay* for more details (poster).

R. Wang, S. Senneville and D. Dumont, *Interannual variability of the freshwater pathways*. 
The general circulation, freshwater pathways, sea ice cycle, polynyas, and mean transports are well represented by the model (given that we look far enough from model boundaries).

The model helps see the big picture and understand what drives the fate of freshwater in the system.

Ongoing work will characterize in more detail the interannual variability and the HBS climate response.
What to do next?

First, **determine what we want to model and study**.
- Coastal erosion
- Sea ice dynamics around islands
- Polynya dynamics
- Deep water formation
- Coastal upwelling
- Contribution of eddies to tracer transport
- The effect of steep bathymetric features
- Snow and rain on ice
- Wave-ice interactions
What to do next?

- Nesting and downscaling
  - Use the large-scale model to force a limited area on a finer grid.
  - Acquire data compatible with the finer scale for model testing.
  - Characterize the internal variability.

- Update the code to improve physical parameterizations

- Add further complexity to the model (biogeochemistry, sediment transport, snow blowing, black carbon, etc.)
Thank you