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Hypoxia in the bottom water of the St. Lawrence Estuary: Is this ecosystem on borrowed time?

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When the rate of oxygen consumption in water exceeds the rate of supply, the oxygen concentration decreases and may reach levels that threaten the survival of many aquatic organisms. Waters with such low oxygen levels are termed severely hypoxic ($[O_2] < 62.5$ μmol L-1). In 2011, the World Resources Institute identified 479 hypoxic coastal zones around the world, including fjords, estuaries, bays, shelves, as well as enclosed and semi-enclosed seas. These hypoxic environments are mainly found in coastal areas as a result of industrial and agricultural fertilizer discharge (i.e. eutrophication), and they develop during summer when the water column is strongly stratified; but hypoxia may also occur naturally and persist year-round.
Historical records reveal that the dissolved oxygen concentration has progressively decreased in the bottom water of the Lower St. Lawrence Estuary (LSLE) during the last century and reached the severe hypoxic threshold in the 1980s where it has hovered ever since. The development of severe hypoxia in the LSLE has been mostly attributed to a gradual change in the properties (e.g. higher temperature, lower dissolved oxygen concentration) of the bottom water that enters the Laurentian Channel (Gulf of St. Lawrence, Eastern Canada). In addition, evidence of eutrophication has been reported in the LSLE, possibly increasing the oxygen demand in the water column and sediment. Increased respiration rates in the bottom water, in response to warming (from 3.3 to 5°C), has also been proposed to explain the increased depletion of oxygen in the Gulf. Nevertheless, whether hypoxia in the bottom water of the Laurentian Channel results from anthropogenic or natural forcings or both remain unclear.
This presentation will examine the processes that govern the spatial distribution of dissolved oxygen in the water column and identify the causes that led to the development of large-scale hypoxia in the bottom waters of the LSLE. A laterally integrated advection-diffusion two-dimensional model was implemented to simulate the spatial distribution of dissolved oxygen and the development of hypoxic conditions in the deep waters of the Laurentian Channel (Estuary and Gulf of St. Lawrence). Our simulations reveal that the horizontal distribution of dissolved oxygen in the bottom waters of the Laurentian Channel is determined by a combination of physical and biogeochemical processes, whereas its vertical distribution is governed by the deep water circulation. This result strongly suggests that the physics of the system and the source water properties are mostly responsible for the oxygen depletion and its distribution pattern in the deep water column.