Notice of the Final Oral Examination for the Degree of Doctor of Philosophy

of

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MSc (Dalhousie University, 2012)
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“Physical Controls on Extremes of Oceanic Carbon and Oxygen in Coastal Waters”

School of Earth and Ocean Sciences

Thursday, August 8, 2019
3:30 P.M.
Clearihue Building
Room B017

Supervisory Committee:
Dr. Adam Monahan, School of Earth and Ocean Sciences, University of Victoria (Co-Supervisor)
Dr. Debbie Ianson, School of Earth and Ocean Sciences, UVic (Co-Supervisor)
Dr. Michael Foreman, School of Earth and Ocean Sciences, UVic (Member)
Dr. Karen Kohfeld, School of Resource and Environmental Management, Simon Fraser University (Outside Member)

External Examiner:
Dr. Richard Matear, Ocean and Climate Dynamics, CSIRO Australia

Chair of Oral Examination:
Dr. Samuel Wong, Department of English, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

Local and remote wind forcing of upwelling along continental shelves of coastal upwelling regions play key roles in driving biogeochemical fluxes, including vertical net fluxes of carbon, oxygen and nutrients. These fluxes are responsible for high primary productivity, which in turn supports a lucrative fishery in these regions. However, the relative contributions of local versus remote wind forcing is not well quantified or understood. This thesis presents results of coherence analyses between currents at a single mooring site (48.5° N, 126° W) in the northern portion of the California Current System (CalCS) from 1989 – 2008 and coincident time series of North America Regional Reanalysis (NARR) 10 m wind stress within the CalCS (36 – 54° N, 120 – 132° W). The two-decade long current records from the three shallowest depths (35, 100 and 175 m) show a remote response to winds from as far south as 36° N. In contrast, only temperature at the deepest depth (400 m) show strong coherences with remote winds. Weaker local wind influence is observed in both the currents and 400 m temperature but is mostly due to the large spatial coherence within the wind field itself. Lack of coherence between remote winds and the 400 m currents suggests that the temperature variations at that depth are driven by vertical motion resulting from poleward travelling coastal trapped waves (CTWs).

In order to understand the effects of this remote forcing on the occurrence and timing of carbon and oxygen extremes in the west coast of Vancouver Island, the coupled physical-biogeochemical model of Ianson and Allen (2002) that simulates carbon and nitrogen cycles in the northern CalCS, has been used. For this purpose the model has been improved in many ways, including the introduction of a mechanistic mixed layer depth, and oxygen cycle. The updated model uses daily resolved time-varying forcing. These improvements allowed for a more realistic simulation of model variables that satisfactorily captured both the mean and variability structures of observational data collected over two decades.

The model was then used to study the effects of stochastically generated local and remote forcing on carbon and oxygen cycles in the study region. Results of a 1020 years long model simulation of present day conditions show remotely forced upwelling intensifies the carbon and oxygen extremes. Local biology plays an important role in these extremes under a wide range of up/downwelling strengths.
Consideration of return periods of carbon and oxygen extremes revealed that carbon and oxygen extremes can be partially decoupled. In the upper layers, episodes of oxygen extremes can be more than twice (2.42 times in shelf and 2.88 times in slope regions) as frequent as those of carbon (measured in this study as the amount of dissolved inorganic carbon, DIC) extremes. In the lower layers, DIC extreme episodes are more frequent (1.29 times in shelf and 1.71 times in slope regions).

In the model upper layers carbon and oxygen extremes are mainly controlled by physical processes while the lower layer extremes are mainly controlled by biology. Exceedance probabilities show the year-to-year variability is stronger in this biologically controlled layer. This result implies that long term observations are required to better define the climatology of carbon and oxygen extremes in the lower layer.

The timing of these extremes is dominated by higher occurrence rates at the edges of the upwelling season. Dominant factors contributing to the carbon and oxygen extremes and their timing were quantified through sensitivity analyses. In particular, oxygen extremes in the model lower layers showed a nonlinear response to changes in phytoplankton growth rate. Decreasing the growth rate by less than 80% generally decreased the lower layer oxygen extreme values below their corresponding baseline values. A further decrease in growth rate rather increased the oxygen extremes in the lower layers.