Response to Comments by Reviewer 2
(Reviews are included in black font; Responses are in blue font)

General comments:
The paper "Diagnosing transit times on the northwestern North Atlantic continental shelf" by Krysten Rutherford and Katja Fennel is a study aiming to detect retention times, mean ages and transport pathways of water-masses of different origin in the northwestern North Atlantic using two passive tracers: dye tracer and age tracer.

In principle the paper is well written and can be already suggested for publication in "Ocean Science" with minor/moderate revision of current state.

Response: We are grateful for the positive assessment and constructive review. Below we a detailed response to all comments and describe how we intend to address them in the revised manuscript.

Major comments/suggestions and questions:

The major concern is the selection of the time period for the analysis. Namely, is there some sort of inter-annual variability in the circulation system that can somehow change the results? For example the authors have not found evidence of strong upwelling events in the region, which have previously been indicated by other authors (e.g. Shadwick et al. 2010 and Burt et al. 2013). According to Shadwick et al. (2010) and references therein, coastal Scotian shelf is a well known for coastal upwelling events and these have been successfully produced also by modelling studies (e.g. Donohue, 2000). In this study, the authors did not find any evidence of upwelling induced transport. Why is that?

Response:
<u>With regard to the length of the simulation:</u> Our model was run for 9 years in the AGE simulations and thus should capture a sufficiently long period for the results not to be unduly influenced by interannual variability.

<u>With regard to upwelling:</u> We would like to clarify the important distinction between coastal upwelling (typically within 10 km of the coast) and upwelling of deep water along the shelf break (at about 200 km from the coast). Our dye tracer experiments can only be used to evaluate upwelling of deep slope water (from below 200 m in the slope region) at the shelf break, but not coastal upwelling in which Scotian Shelf water from below the seasonal thermocline upwells in the vicinity of the coast. In summer, winds can be southwesterly along the coast of Nova Scotia, which is the upwelling-favourable direction and this frequently leads to coastal upwelling. Petrie et al. (1987) used satellite images of the region to show the development of a band of cool water along the southern shore of Nova Scotia over the month of July 1984 caused by upwelling-favourable winds (see Figure below). The modeling study by Donohue (2000) reproduced the event studied by Petrie et al. This coastal upwelling event occurred, as stated by Petrie et al. (1987), "over a coastal strip about 10 km wide and 500 km long."

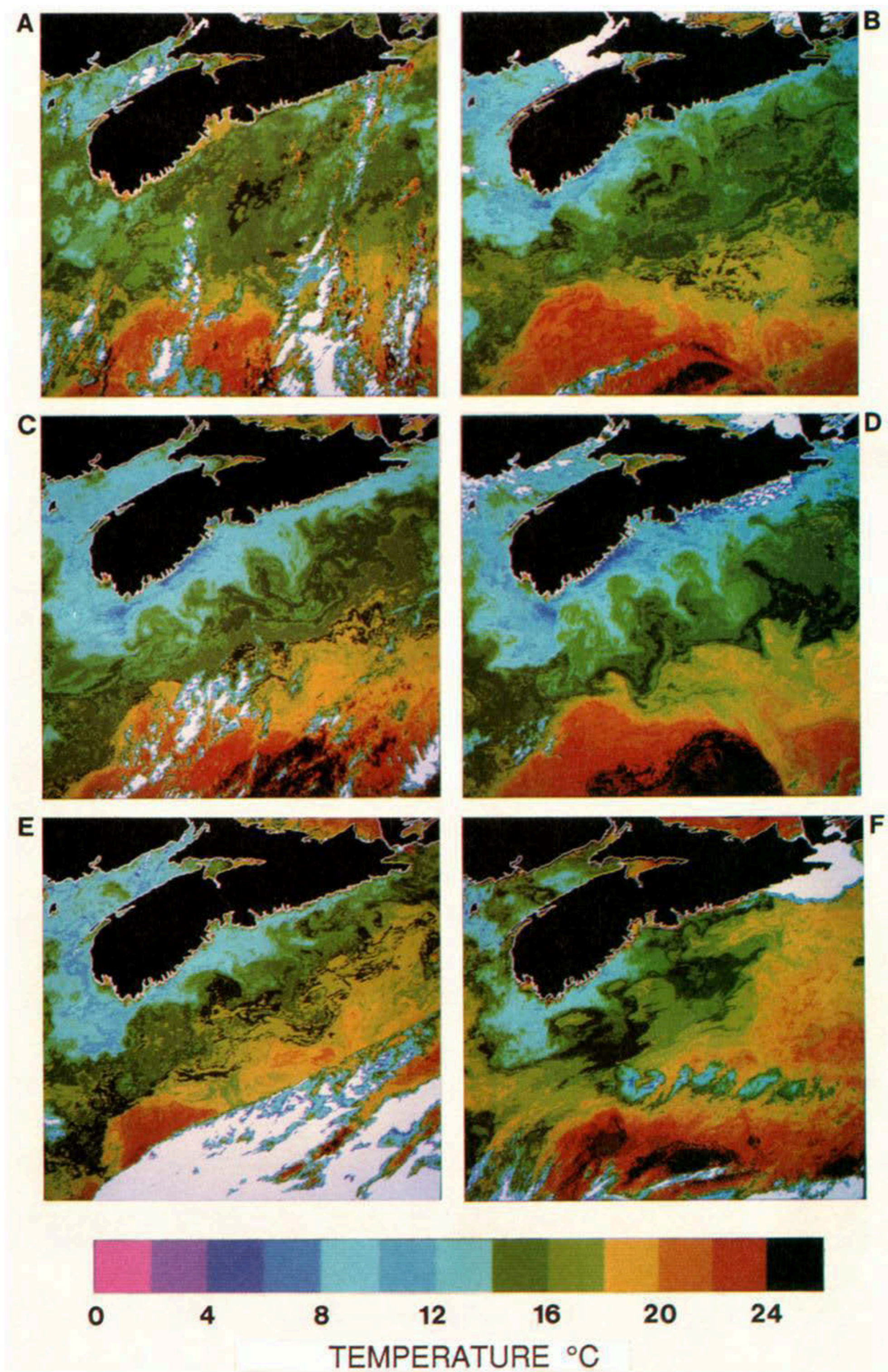


Figure 1: Satellite infrared imagery of sea surface temperatures from (a) July 7, (b) July 14, (c) July 21, (d) July 25, (e) July 31 and (f) August 6, 1984. Image is from Petrie et al. (1987) illustrating narrow band of cool water on the southern shore of Nova Scotia during a period of upwelling-favourable winds.

A more recent example from Shan (2016) showing both satellite images and simulated model snapshots of SST in July 2012 is given below and illustrates again the band of cool upwelled waters on the southern shore of Nova Scotia in the vicinity of the coast. Shan (2016) noted two distinct upwelling events during 2012, one that peaked July 22 and the other September 1, 2012. Shadwick et al. (2010) and Burt et al. (2013) did not show any direct evidence of upwelling; instead they invoked it as an explanation of their carbon observations.

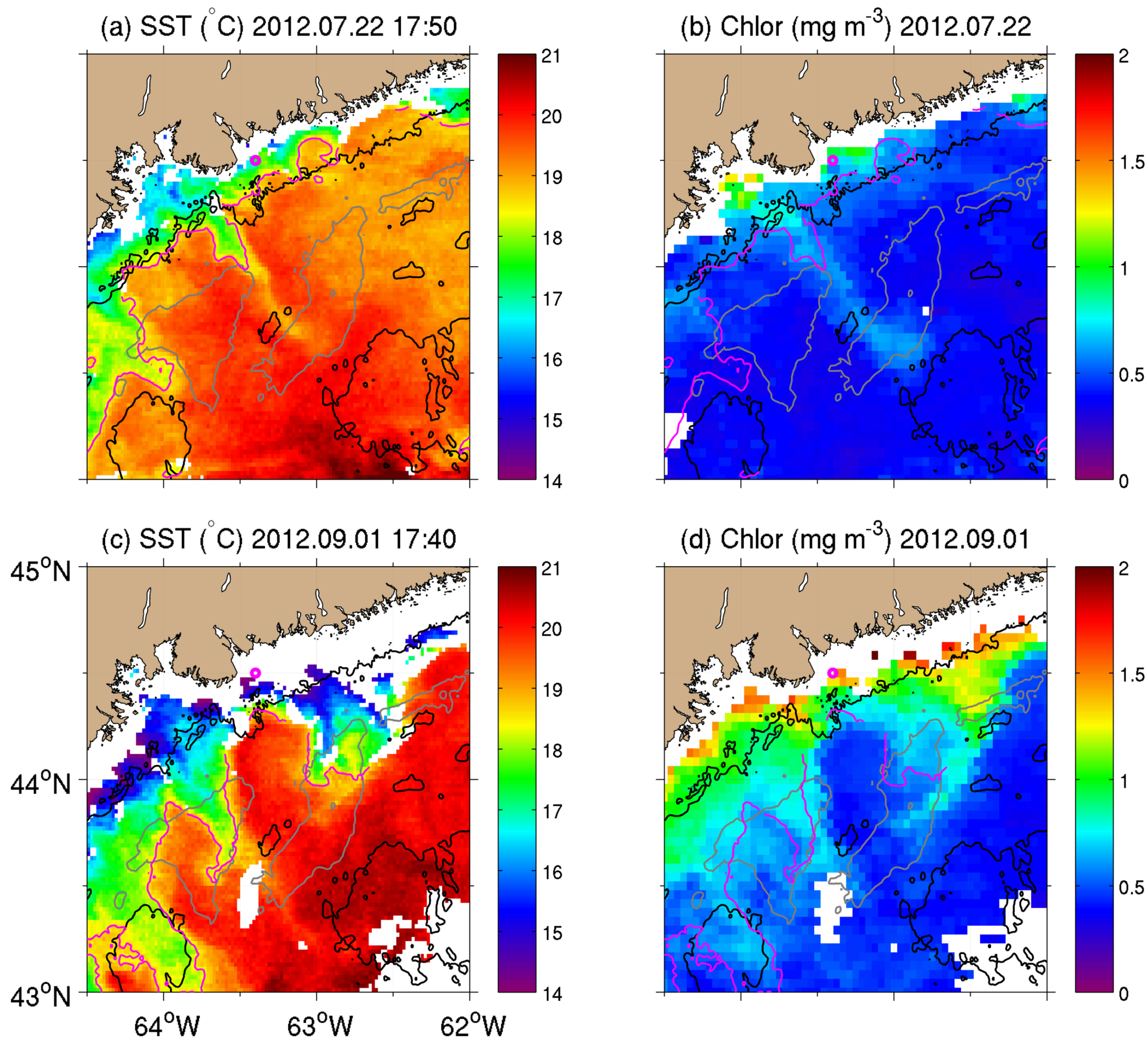


Figure 2: MODIS satellite remote sensing data of SST and Chlorophyll concentrations over the central Scotian Shelf and adjacent waters from July 22 and September 1, 2012 (from Shan 2016). Note that the shelf break is outside the frames. 100 m and 200 m isobaths are shown in black and gray contour lines, respectively.

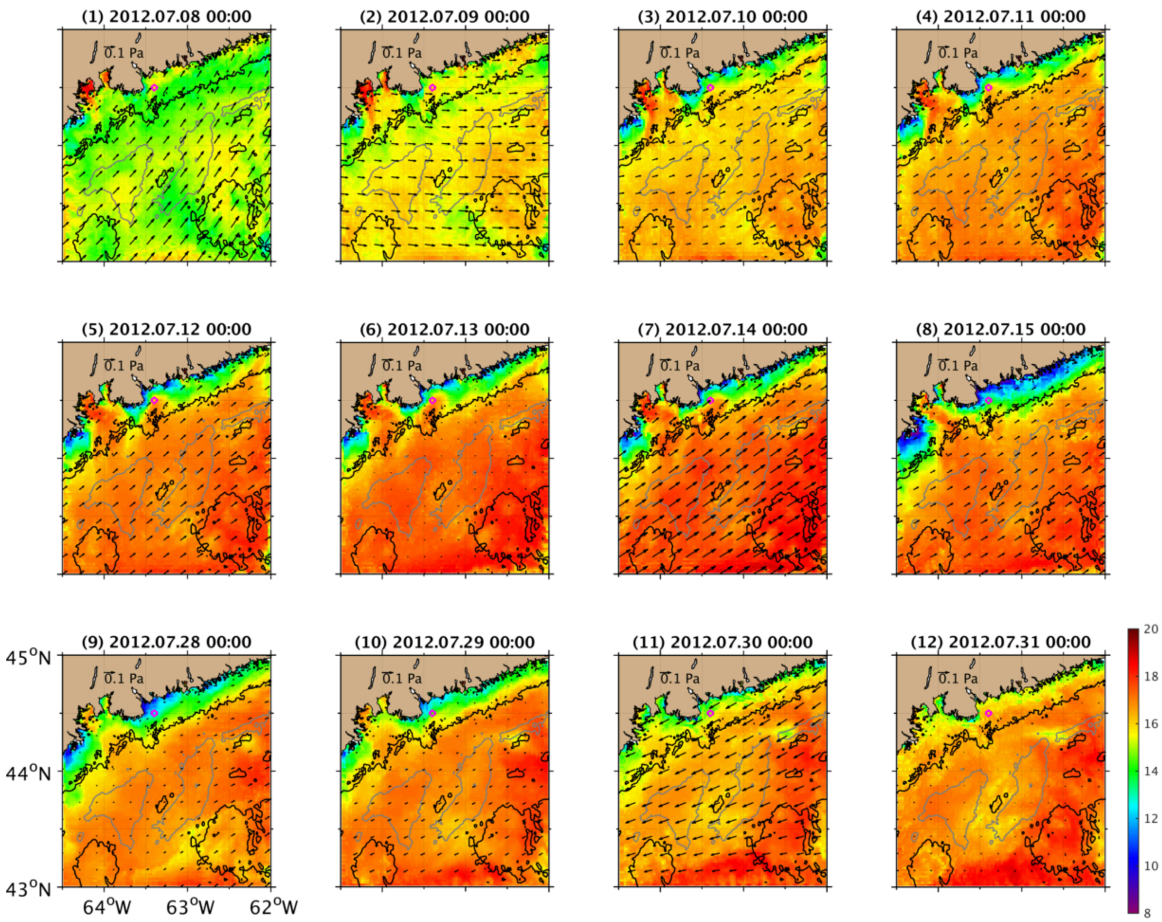
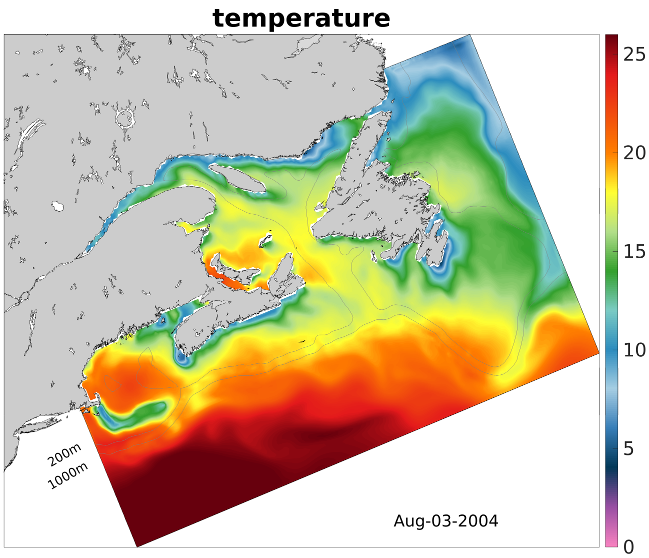
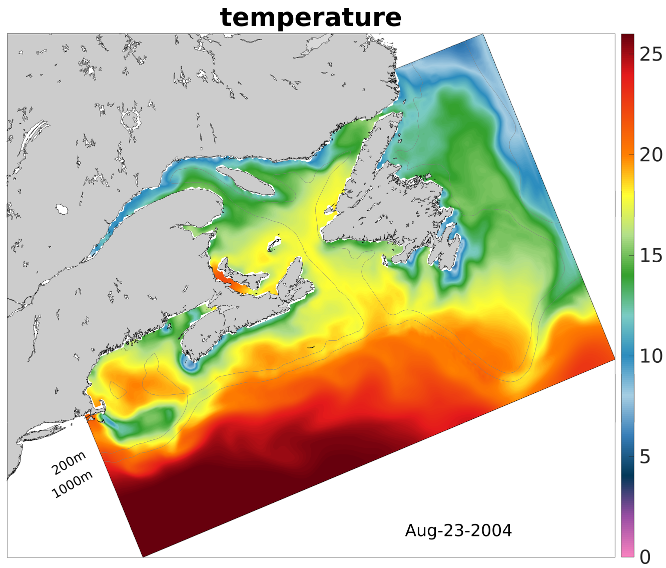


Figure 3: Snapshots of simulated SST over the central Scotian Shelf in July 2012 with instantaneous wind stress vectors plotting as black arrows (DalCoast-CSS model from Shan 2016).

Our model produces coastal upwelling events similar to those observed. The snapshots of our model simulation below show the narrow band of cool upwelled water along the southern coast of Nova Scotia.

We emphasize again that the shelf break is ~ 200 km from shore and propose adding some text to the manuscript to clarify these distinct types of upwelling.





References:

Donohue, S. M. A numerical model of an upwelling event off the coast of Nova Scotia, MSc thesis, Royal Military College of Canada, Kingston, ON, 2000.

Petrie, B., B. Topliss, and D. Wright, Coastal upwelling and eddy development off Nova Scotia, *Journal of Geophysical Research*, 92, 12979-12991, 1987.

Shan, S. Eulerian and Lagrangian studies of circulation on the Scotian Shelf and adjacent deep waters of the North Atlantic with biological implications, PhD thesis, Dalhousie University, Halifax, NS, 2016.

Second concern is associated with the first one: namely, if the selected period did not have any upwelling events in the region, perhaps the study should be extended for longer period to have full view of the circulation in the region. Nevertheless, if there were upwelling events during the selected period, but the model was unable to re-produce them, perhaps the global atmospheric forcing (ERA-Interim) should be replaced by some regional product, which might have better spatial resolution and also better representation of the local weather climate – the wind patterns for example.

Response: As stated above, our model does indeed capture the **coastal** upwelling that occurs on the Scotian Shelf as a result of upwelling-favourable winds, therefore we do not believe we need to consider replacing our atmospheric forcings.

Third concern is also somehow associated with the first one: namely, the temperature and salinity are nudged towards climatology in the open boundaries. This should remove inter-annual variability of temperature and salinity at the boundaries, but how large is the latter?

Response: It is true that there is no interannual variability in the boundary conditions; however, coastal upwelling is driven primarily by wind forcing which does vary interannually. The model does display interannual variability in its simulated coastal upwelling.

Minor comments/suggestions and questions:

1. Use chronological order of references in the text.

Response: This will be updated.

2. Page 2, section "Introduction", lines 13-16: Authors state that for the region this is the first study of residence times, transport pathways and timescales in the NW North Atlantic. Nevertheless, for discussion, they have found several studies, which to compare their results to. Therefore, I would add general statement about other studies.

Response: We will update these lines to the following: "Although previous studies have quantified shelf basin particle retention (Rogers 2015), shelf residence times as part of global studies (Bourgeois et al. 2016, Sharples et al. 2017), and transport times from the St. Lawrence River to the Scotian Shelf (Sutcliffe et al. 1976, Smith 1989, Shan et al. 2016), this is the first comprehensive analysis of residence times, transport pathways and timescales in the NW North Atlantic."

3. Please state explicitly if you are using ERA-Interim forcing instead of too general statement in page 8 lines 9-11: . . . surface forcing from the European Centre for Medium-Range Weather Forcasts (ECMWF) global atmospheric reanalysis Dee et al. (2011) . . .

Response: We will update to specify that it is ECMWF ERA-Interim forcing

4. The location of the stations used for histograms in Figure 8b could also be shown in Figure 1.

Response: We will add the station locations to either Figure 1 or Figure 2.

5. The number format in Table 1 could be consistent – there is no need for scientific notation and I recommend replacing scientific notation with decimal notation.

Response: We will update and remove the scientific notation.

6. In Figures 4 and 9 the initial location of tracers could be shown by shading the geographic area or drawing solid contours.

Response: We will add the location of the initial dye tracer regions to Figure 4 and 9.

7. Page 17, line 15: be more precise with the origin of the differences with Sharples et al. (2017). The statement is too general.

Response: We will add a sentence detailing some of the specifics from Sharples et al. (2017). Specifically, we will emphasize that their focus is on calculating river plume export across the shelf break without numerical models and that they divide global continental shelves based on Sp ratio (whether $Sp < 1$ or $Sp > 1$ will determine the assumptions used to calculate residence time). Since the Scotian Shelf has an $Sp <1$ it is assumed that the salinity plume is confined to the shelf and that exchange with open ocean is controlled by exchange across the shelf break. Residence time is therefore assumed to be controlled by Ekman cross-shelf break transport as well as a lumped transport that factors in mean non-wind-driven export that can affect residence times on such shelves.

8. Can dye and age tracer leave the model region i.e. are open boundaries used also for those tracers?

Response: Yes, the boundaries are open for dye and age tracers and they can therefore leave the model domain.