Identifying and characterizing shelf edge cascading on the multi-decadal timescales.

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Background: Cascading (or shelf convection) is a type of density-driven current, in which dense water is formed over continental shelves due to cooling/freezing events and descends down the slope to a greater depth (Shapiro *et al.*, 2003) (see figure 1) and as such contributes to the Meridional Overturning Circulation. Cascading is thought to be one of the major players in shelf-ocean interaction and to contribute to carbon export from continental shelves to the open ocean. Hence, it might influence the long-term sequestration of the carbon drawn-down from the atmosphere by biological production in shelf seas, with consequences for global climate (Huthnance *et al.*, 2009, Holt *et al.*, 2009). Cascading (or at least its outcome) has been widely observed worldwide (Ivanov *et al.*, 2004), including the Arctic Ocean (e.g. Schauer and Fahrbach, 1999) and the European Seas (e.g. Canals *et al.*, 2009). However because it is an episodic process and difficult to observe, its regional importance over multi-decadal time scales is uncertain. Moreover it is generally poorly represented in large scale numerical models.

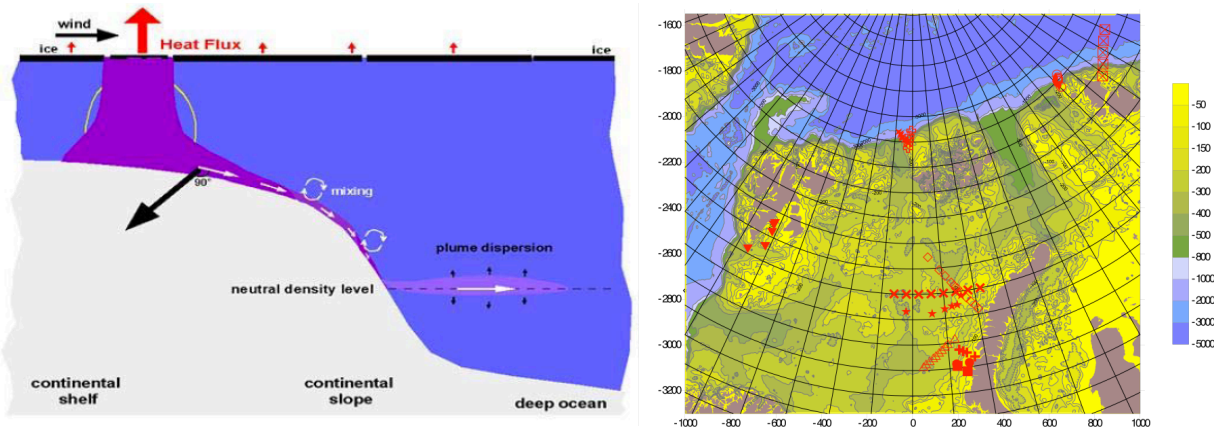

Figure. Left panel: Illustration of cascading mechanism. Right panel: Sample locations of shelf edge cascades from observations (Shapiro et al, 2003, Ivanov et al, 2004).

Hypothesis

The main the hypotheses to test are:

1. Physical conditions for initiation of cascading events can be identified from the output of regional scale ocean models.

2. The cumulative effect of cascading events have an important role in ocean-shelf exchange that is significant for global biogeochemical cycles and oceanic water mass formation.

Workplan

Numerical simulations, both already completed and planned, provide a substantial data set which will be used to search for the preconditioning and the consequences of dense water cascades across the shelf break. The following model outputs will be used in study: (i) POLCOMS at 12 km resolution for the NW European shelf (Holt *et al* 2009); (ii) NEMO at 18km and 3km for the Arctic Ocean. Currently there are 45-years model simulation data for the European shelf. The Arctic Ocean simulation data will be available for this PhD project from then ongoing NERC ROAM (Ocean Acidification) project. Higher resolution model simulations will also be available during the project e.g. 1.8km NW European shelf based on Holt and Proctor (2008).

This study will employ the methodology for the identification of cascades from the observational data sets developed in the EU INTAS project 'Cascading' (led by J. Huthnance and G. Shapiro, see e.g. Ivanov et al, 2004, Shapiro et al, 2003). This project will be carried out in the framework of NERC strategic research programmes (e.g. Arctic Research Programme and the Ocean-Shelf Exchange Programme).
The program of work includes the following major steps:

1. Identification of locations and time frames where formation of physical conditions for shelf edge cascades are most likely. The student will examine the model output and write scripts for reading and analysing data and provide the dataset for the most favourable locations of cascading events.
2. Investigation of models ability to identify shelf edge cascade at different model resolutions, configurations and regions. The student will analyse hydrological preconditions of cascading events in the multi-decadal framework.

Further tasks include:

3. Test the parameterisation of shelf edge cascading being developed within other ongoing projects between University of Plymouth and NOC (Liverpool).
4. Contribute to the implementation of cascading parameterization in regional models. The student will gain experience working with the NEMO model.

Schedule :

Year 1: Taught courses at University of Plymouth, literature review, familiarising with cascading observational data, NOC and University of Plymouth 3-D modelling studies.

Year 2: Study of cascades on the NW European shelf.

Year 3: Study of cascades in the Arctic Ocean. Write up.

The PhD student will be registered at the University of Plymouth, but will carry out about 50% of their work at the NOC, Liverpool, in particular in years 2 and 3.

Training provided

The student will participate in the regular PhD training programme offered by the School of Marine Science and Engineering and the Postgraduate School, University of

Plymouth, as well as any appropriate courses offered at NOC. The project will provide pathways for the student to develop their skills in numerical modelling techniques, from input data preparation to coding to interpretation of the model results. The student will get experience in running and post-processing of model simulations on high performance computer systems. The supervisors will also provide guidance in the development of a solid grounding in geophysical fluid dynamics and physical oceanography, and the preparation of scientific papers. Applicants should have skills in a numerate science, such as physics, mathematics, physical oceanography or meteorology, and a willingness to engage in all aspects of numerical modelling. The student will be encouraged to participate in international summer schools and PhD events organised by NERC, present their results at research seminars, national and international conferences. The student will be encouraged to participate in oceanographic fieldwork as opportunities arise to familiarise themselves with data gathering techniques.

Basic knowledge of ocean science is desirable. Some basic knowledge of a programming language (FORTRAN, MATLAB, C or similar) is essential. The successful candidate will display a willingness to engage with physical aspects of shelf edge exchange processes and their potential impact on climate. Funding for this studentship is restricted to UK and EU nationals who fulfil NERC's eligibility requirements. More information is available from the NERC website: http://www.nerc.ac.uk/funding/available/postgrad/eligibility.asp

References

Canals M., Danovaro R., Heussner S., Lykousis V., Puig P., Trincardi F., Calafat A.M., de Madron X.D. , Palanques A., Sanchez-Vidal A., Cascades in Mediterranean submarine grand canyons, 2009. *Journal Of Oceanography*, 22(1), 26-43.

Holt, J.; Wakelin, S.; Huthnance, J. 2009 Down-welling circulation of the northwest European continental shelf: A driving mechanism for the continental shelf carbon pump. *Geophys. Res. Let.*, 36, L14602. 10.1029/2009GL038997

Holt, J.T. and Proctor, R., 2008. The seasonal circulation and volume transport on the northwest European continental shelf: a fine-resolution model study. *J. Geophys. Res.*, 113: doi: 10.1029/2006JC004034

Huthnance, J. M.; Holt, J. T.; Wakelin, S. L.. 2009 Deep ocean exchange with west-European shelf seas. *Ocean Science*, 5. 621-634.

Ivanov V.V., G.I.Shapiro, J.M.Huthnance, D.L Aleynik, P.N. Golovin, 2004.*Progress in oceanography*, 60, 47-98.

Shapiro G.I., Huthnance J.M., Ivanov V.V., 2003. Dense water cascading off the continental shelf. *J. Geophys Res-Oceans*, 108 (C12): art. no. 3390, Dec 30, 2003

Schauer U. and E. Fahrbach, 1999. A dense bottom water plume in the western Barents Sea: downstream modification and interannual variability, *Deep-Sea Res. Part I* ***46*** , pp. 2095–2108