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Supporting Information for

# A persistent deep anticyclonic vortex in the Rockall Trough sustained by anticyclonic vortices shed from the slope current and wintertime convection

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## Additional Supporting Information (Files uploaded separately)

Caption for Movie S1

## Introduction

Included are all supporting figures and tables.

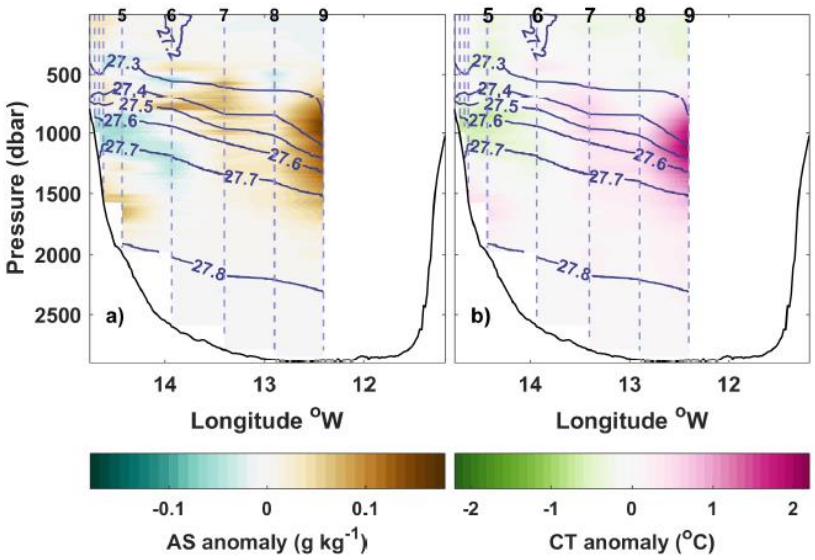


**Fig. S1.** **In-situ derived absolute salinity (AS) g kg) and conservative temperature (CT) anomalies (C), left and right panels respectively, in January 2012. In both panels dark grey lines represent isopycnals, computed using potential density (σθ) (kg m-3), referenced to 0 dbar, with numbers along isopycnals representing the isopycnal values. Light grey dashed lines representative of deep stations locations, i.e., vertical profiles, with stations' numbers displayed on top of the panels. Property anomalies calculated relative to respective data points mean values for the overall period of ship-board data availability (2006-2013).**

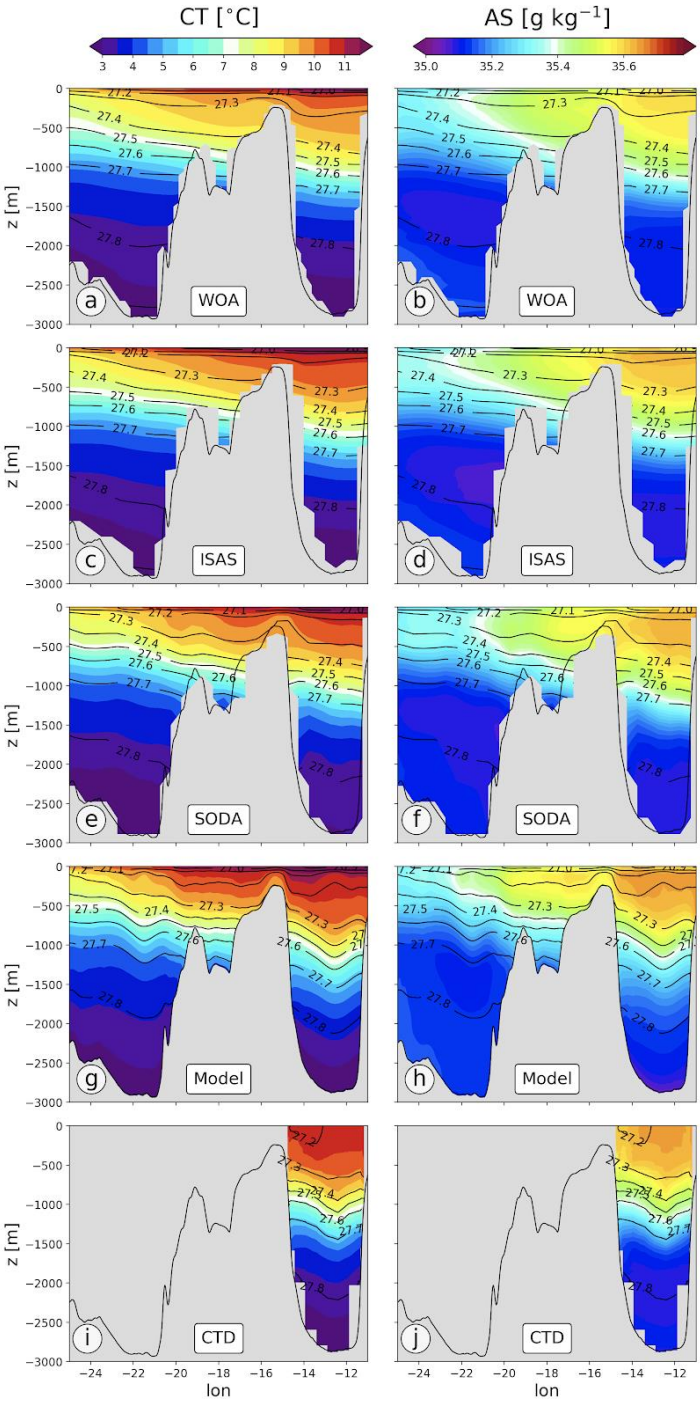


**Fig. S2.** **Conservative Temperature (CT) and (right) Absolute salinity (AS) along the RT transect line (Fig. 1) from a, b) WOA18 (2005-2017), c, d) ISAS15 (2002-2015), e, f) SODA reanalysis (2010-2011), g, h) model (2010-2011) and i, j) CTD (winters 2006-2013).**

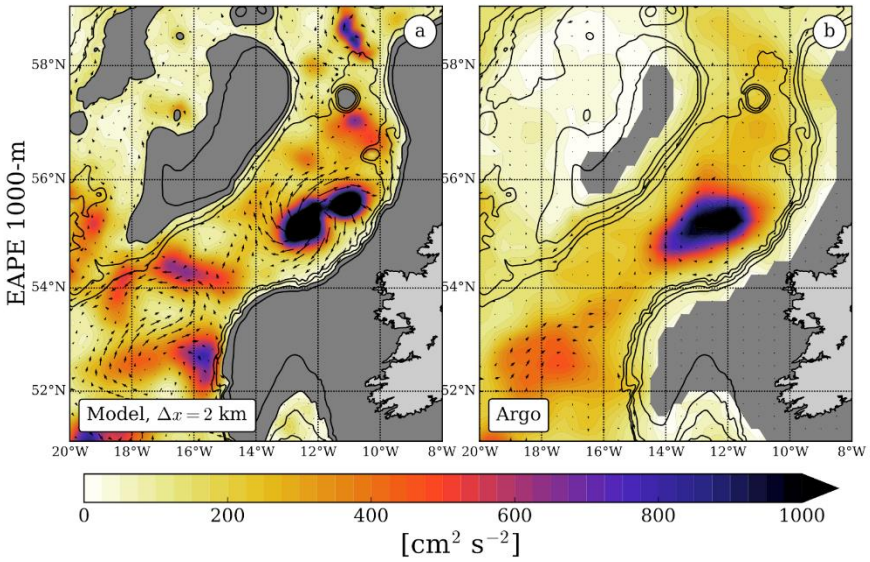


**Fig. S3. Mean eddy available potential energy (EAPE) and currents at 1000 m depth from a) the model and b) the Argo database using the method of Roullet et al. (2014).**

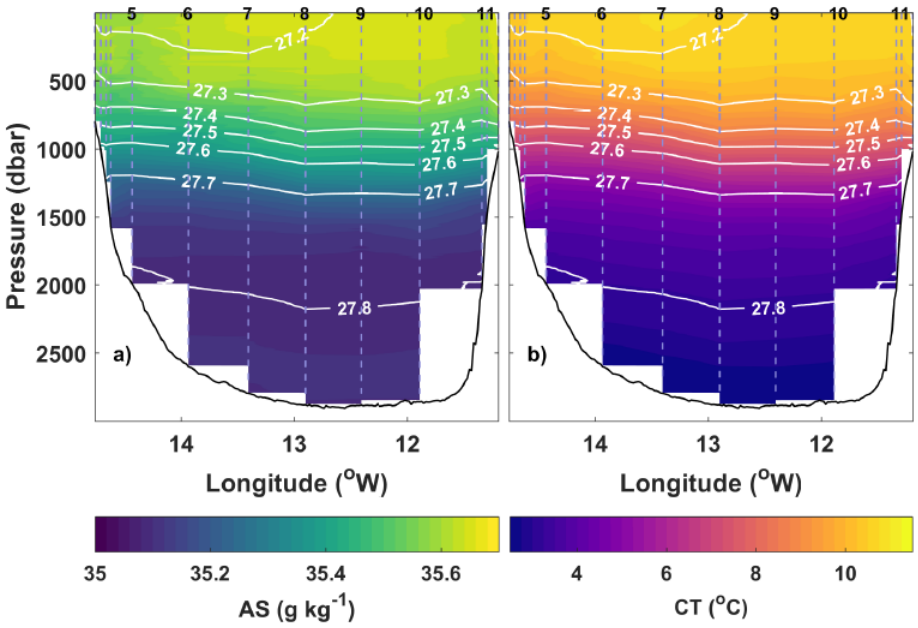


**Fig. S4.** **Longitude-pressure in-situ-derived 2006, 2009, 2010 and 2013 mean a) absolute salinity (AS) (g kg$^{-1}$) and b) conservative temperature CT (°C). Light grey dashed lines in all plots are representative of stations locations, *i.e.*, vertical profiles, with deep stations numbered on top of all panels. Dark grey lines show potential density ($\sigma_0$) (kg m$^{-3}$), referenced to 0 dbar.**

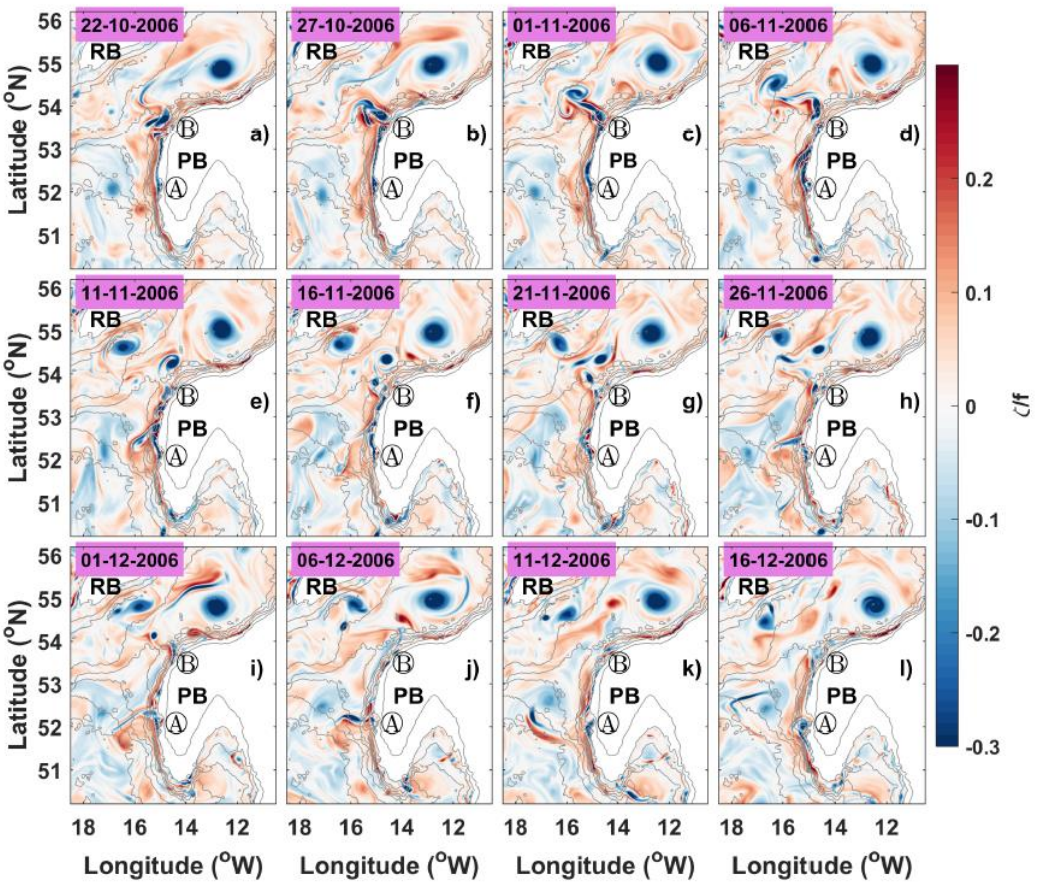


**Fig. S5.** **Model-derived relative vorticity, $\zeta/f$, at 1000 m depth for selected October 2006 - December 2006 dates, with a 5-day time-step, starting on 22nd of October, 2006, finishing on 16th of December, 2006, with a) 22nd of Oct, b) 27th of Oct, c) 1st of Nov, d) 6th of Nov, e) 11th of Nov, f) 16th of Nov, g) 21st of Nov, h) 26th of Nov, i) 1st of Dec, j) 6th of Dec, k) 11th of Dec, l) 16th of Dec. Light grey lines show bathymetry (500 m level-step). Vorticity filament separation, near 52 °N and near 53.5 °N, and generation of small-scale vortices along the Porcupine slope is evident. The newly formed vortices travel further into the trough, feeding the Rockall Trough anticyclone. Some of the small, newly generated vortices exhibit westward propagation, some reaching the western slopes of the Rockall Bank, and some making their way into the marginal subpolar northeast NA. Circled black A and B letters denote candidate 'prime spots' for negative potential vorticity filaments separation due to bottom topography - slope current. Range of $\zeta/f$ restricted between -0.3 and 0.3 to help visualising vorticity generation and filament separation along the Porcupine slope. Letter annotations as in Fig. 1.**

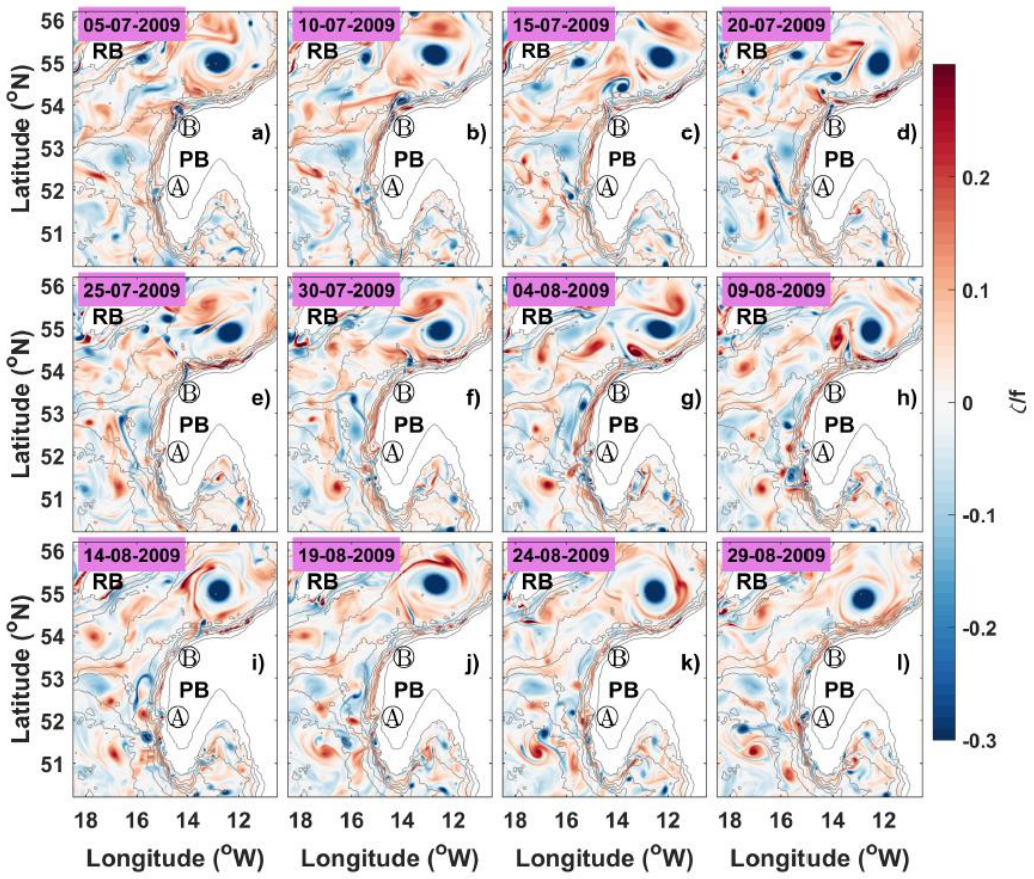


**Fig. S6.** **Model-derived snapshots sequence of normalized with respect to f relative vorticity, $\zeta/f$, at 1000 m depth for selected July 2009 – August 2009 dates, with a 5-day time-step, starting on 5th of July, 2009, finishing on 29th of August, 2009, with a) 5th of Jul, b) 10th of Jul, c) 15th of Jul, d) 20th of Jul, e) 25th of Jul, f) 30th of Jul, g) 4th of Aug, h) 9th of Aug, i) 14th of Aug, j) 19th of Aug, k) 24th of Aug, l) 29th of Aug. Light grey lines show bathymetry (500 m level-step). Vorticity filament separation, near 52 °N and near 53.5 °N, and generation of small-scale vortices along the Porcupine slope is evident. The newly formed vortices travel further into the trough, feeding the Rockall Trough anticyclone. Some of the small, newly generated vortices exhibit westward propagation, some reaching the western slopes of the Rockall Bank, and some making their way into the marginal subpolar northeast NA. Circled black A and B letters denote candidate 'prime spots' for negative potential vorticity filaments separation due to bottom topography - slope current. Range of $\zeta/f$ restricted between -0.3 and 0.3 to help visualising vorticity generation and filament separation along the Porcupine slope. Letter annotations as in Fig. 1.**

| Year | MI Cruise ID | ICES reference ID | Start Date | End Date |
|---|---|---|---|---|
| 2006 | CE0602 | 200645011 | 26-01-006 | 02-02-2006 |
| 2007 | CE0702 | 200745002 | 24-01-2007 | 02-02-2007 |
| 2008 | - | - | - | - |
| 2009 | CE0903 | 200945001 | 05-02-2009 | 15-02-2009 |
| 2010 | CE10002 | 201045001 | 05-02-2010 | 17-02-2010 |
| 2011 | CE11001 | 201145001 | 03-01-2011 | 12-01-2011 |
| 2012 | CE12001 | 201245001 | 03-01-2012 | 12-01-2012 |
| 2013 | CE13001 | 201345001 | 05-01-2013 | 20-01-2013 |

**Table S1. Details of ship-board surveys, conducted by Marine Institute (MI) Ireland during 2006-20013 wintertime period, along 54 °N-56 °N transect line.**

| Station # | Depth (m) of missing temperature and salinity data<br>*all noted missing temperature values correspond to missing salinity values as well; values in red are additional missing salinity values | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2006 | 2007 | 2009 | 2010 | 2011 | 2012 | 2013 |
| 1 | | | | | 1, 2, 3, 4 | 1, 2, 784 | |
| 2 | 4, 9, 10, 12, 13, 912 | 1,2 | 1, 2 | 1 | 1, 2, 840, 841, 854 | 1, 886 | 1 |
| 3 | | 1,2 | 1, 2, 3 | 1 | 1, 2, 3, 988, 1022, 1140 | 1, 811, 812, 882 | |
| 4 | 815, 874, 1002 | 1, 2, 3, 4, 5 | 1, 2, 453, 454 | 1 | 1, 2, 3, 896, 903, 904, 1004 | 1, 2, 769, 927 | 1, 2 |
| 5 | 1, 2, 3, 4, 5, 6, 7 | 1, 2, 3, 4, 5, 6 | 1, 2 | | 1, 2, 3, 4 | 1, 2 | 1, 2, 3 |
| 6 | 817 | | | | 1, 2, 3 | 1, 2, 775, 784, 798, 800, 804, 805, 810, 812, 816, 817, 820, 825, 858, 950, 981, 985, 1024, 1025, 1059, 1070, 1079, 1086, 1087, 1088, 1092, 1093, 1101, 1128, 1185, 1186, 1269, 1270 | 1, 2, 3, 4 |
| 7 | 1025 | 1, 2, 3, 4, 5 | | 1 | 1, 2, 3, 4, 5, 6 | 1, 2, 1031 | 1, 2, 3, 4, 5, 1067 |
| 8 | 1, 2, 3 | | 1, 2 | 1 | 1, 2, 3 | 1, 976 | 1, 2 |
| 9 | 1198,1199 | 1, 2, 3, 4, 5, 6 | | 1 | 1, 2, 3, 4 | 1, 7 | Not sampled |
| 10 | 1057 | | 1, 2 | | 1, 2, 3 | Not sampled | Not sampled |
| 11 | | 1 | | | 1, 2, 3 | Not sampled | |
| 12 | | | | | 1, 2, 3, 4, 5, 6, 7 | Not sampled | 1, 2, 3 |
| 13 | 917 | | Not sampled | | | 1, 2, 816, 819, 955 | Not sampled |

**Table S2.** **Summary of temperature and conductivity data gaps in the vertical, where conductivity missing data, representative of salinity data gaps at depth, shown in red; note no survey in 2008.**

| Property anomaly | 2007 | | 2011 | |
|---|---|---|---|---|
| | Overall anticyclone's anomaly | Anomaly within core centre | Overall anticyclone's anomaly | Anomaly within core centre |
| Absolute salinity (AS) [g $kg^{-1}$] | 0.12 (± 0.03) | 0.17 (993 m) | 0.11 (± 0.02) | 0.16 (909 m) |
| Conservative temperature (CT) [°C] | 1.26 (± 0.53) | 2.16 (1067 m) | 1.31 (± 0.46) | 2.02 (1129 m) |
| Potential density ($\sigma_\theta$) [kg $m^{-3}$] | -0.09 (± 0.06) | -0.20 (1091 m) | -0.10 (± 0.06) | -0.21 (1093 m) |
| Potential Vorticity (PV) [$m^{-1}$ $s^{-1}$] | $-1.33 \times 10^{-12}$ ($\pm 2.10 \times 10^{-11}$) | $-9.65 \times 10^{-11}$ (1010 m) | $-4.47 \times 10^{-12}$ ($\pm 2.40 \times 10^{-11}$) | $-1.11 \times 10^{-10}$ (1033 m) |

**Table S3. In-situ derived anomalies of absolute salinity (AS), conservative temperature (CT) and potential vorticity ($PV(Q_{str}) = fN^2/g$) values in January 2007 and January 2011, ± 1 standard deviations values enclosed in brackets. Presented are also maximum positive AS, CT and negative stretching PV values, found within the anticyclone's core regions, embedded within the 600-1550 m and 650-1550 m depth ranges in 2007 and 2011 respectively.**

| Water mass/Limits | Conservative temperature [°C] | | Absolute salinity [g $kg^{-1}$] | | Potential density [g $m^{-3}$] | |
|---|---|---|---|---|---|---|
| | Lower | Upper | Lower | Upper | Lower | Upper |
| ENACW | 11.00 | 12.000 | 35.510 | 35.760 | 27.020 | 27.200 |
| SAIW | 5.020 | 8.450 | 35.115 | 35.260 | 27.250 | 27.650 |
| MOW | 7.900 | 9.400 | 35.560 | 35.650 | 27.410 | 27.600 |
| LSW | 3.000 | 3.900 | 35.065 | 35.075 | 27.730 | 27.810 |
| AABW | 2.550 | 2.750 | 35.106 | 35.120 | 27.870 | 27.887 |
| LDW | 2.100 | 2.250 | 35.075 | 35.095 | 27.880 | 27.900 |

**Table S4.** **Boundary conditions (ranges) of conservative temperature (CT) (°C), absolute salinity (AS) (g $kg^{-1}$) and potential density ($\sigma_0$) (kg $m^{-3}$) of water masses, considered for the mixing triangle approach (subsection 2.3.2). All ranges defined in local context, based on CTD-derived T/S diagram for all 2006-2013 wintertime CTD data, collected along ~53-54/55 °N (Fig. 5a).**

**Movie S1.** **ASJGMLCLHYR_JGR_Oceans_2019JC015905_ms01**