

Supplementary Notes

Table S1- A summary of maximum dFe ($\pm$ range of duplicate analyses) and dMn ($\pm$ 1 standard deviation of triplicate analyses) concentrations observed at stations OOI, TN and TS for hydrothermal plume influenced waters. At station TN and TS, the maximum concentrations of dFe and dMn were observed at the same depth. At station OOI, the maximum concentration of dFe was shallower than the maximum concentration of dMn. The southwards shoaling of depth of maximum trace metal concentration is consistent with a shoaling density surface (Fig. S1). Note that the profile maximum dFe concentration (0.94 ± 0.03 nM) for station TS was observed in near bottom waters (4889 m). Maximum xsHe concentration and associated depth at 88°W near OOI (see Figure 1).

Station (latitude)	Max dFe (nM)	Depth (m)	Max dMn (nM)	Depth (m)	Max xsHe (fM)	Depth (m)
OOI (-54.4)	0.96 ± 0.00	2506	0.34 ± 0.02	2808	0.49	2291
TN (-57.0)	0.70 ± 0.01	2503	0.39 ± 0.00	2503		
TS (-60.0)	0.62 ± 0.04	1806	0.24 ± 0.01	1806		
	0.60 ± 0.04	2005	0.24 ± 0.01	2005		

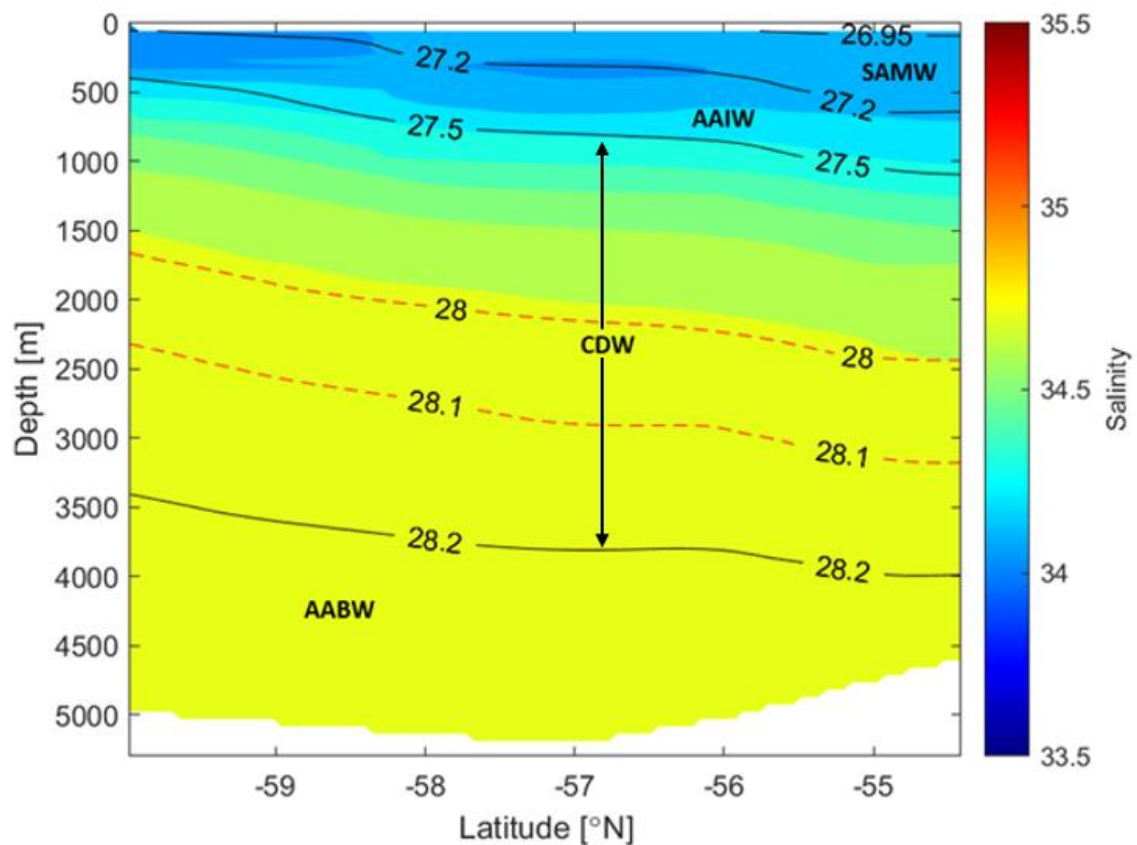


Figure S1. Salinity measured by 7 CTD casts within 54-60°S, 90°W between 13-31st December 2019. Overlain are contours of neutral density [kg m^{-3}]. Black solid contours mark the boundaries of Subantarctic Mode Water (SAMW), Antarctic Intermediate Water (AAIW), Circumpolar Deep Water (CDW) and Antarctic Bottom Water (AABW), as determined by Tamsitt et al. (2020)¹ and Naveira-Garabato et al. (2016)². Red dashed contours demonstrate the density bounds of the observed trace metal signal that is attributed to hydrothermal activity. The location of the water masses along the transect from 54-60°S, 90°W were determined from literature specific to the south-east Pacific. The bound between Subantarctic Mode Water (SAMW) and Tropical Water (TW) is 26.95 kg m^{-3} neutral density¹, the Antarctic Intermediate Water (AABW) bounds are $27.2\text{-}27.5 \text{ kg m}^{-3}$ neutral density² and the bound between Circumpolar Deep Water (CDW) and Antarctic Bottom Water (AABW) is 28.2 kg m^{-3} neutral density².

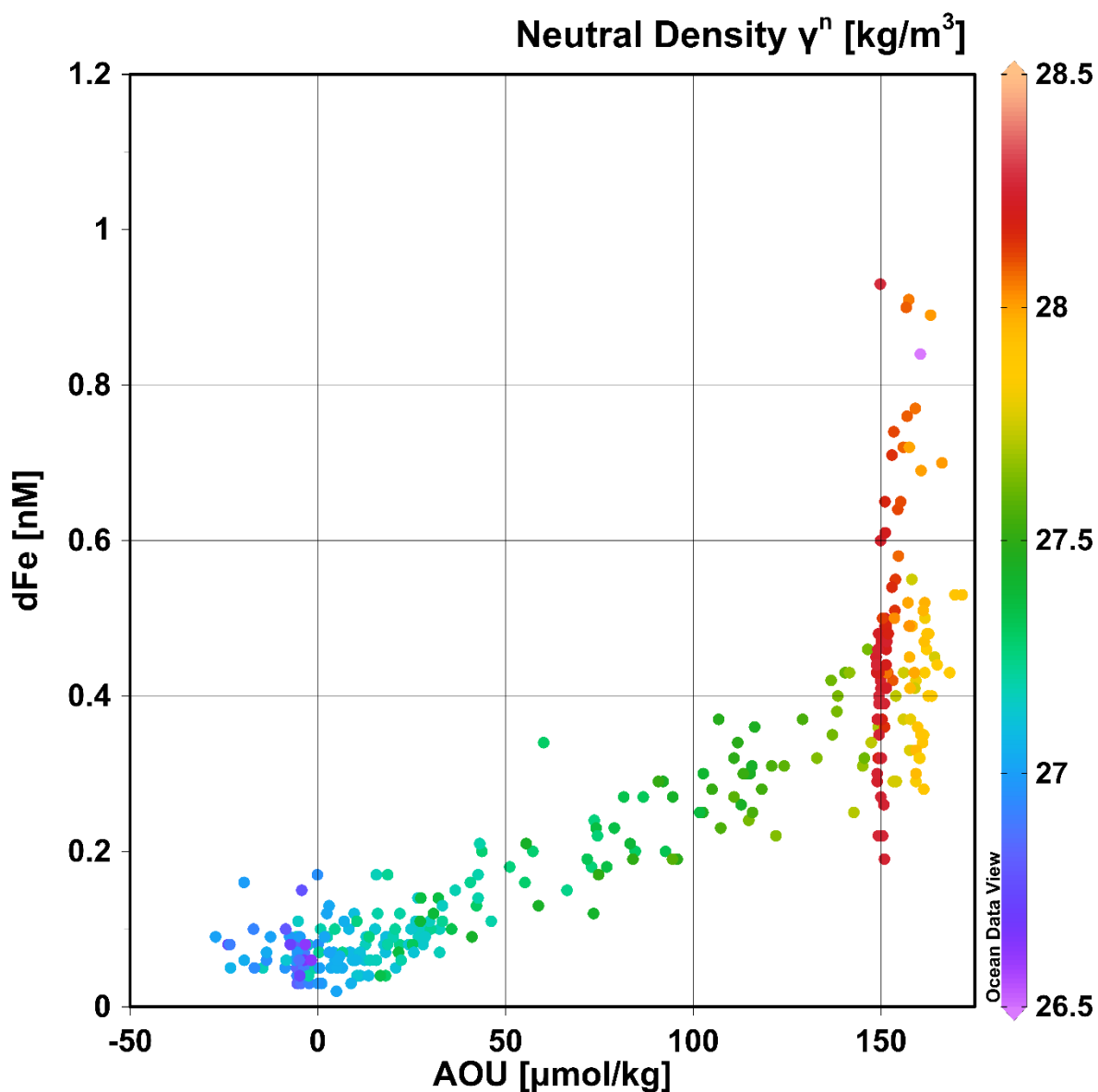


Figure S2. All dFe data from the transect plotted against Apparent Oxygen Utilisation (AOU).

We plot dFe against apparent oxygen utilisation (AOU) from surface waters to a neutral density of $\sim 28.0 \text{ kg m}^{-3}$ to investigate whether remineralisation of organic material could account for the increase in dFe concentration in deep waters. An approximately linear relationship is observed from the surface waters to a neutral density of $< 28.0 \text{ kg m}^{-3}$. The enhanced dFe signal observed at 2000-4000m depth around neutral density of $\sim 28.1 \text{ kg m}^{-3}$ clearly deviates from the linear dFe-AOU trend observed in shallower waters, suggesting this is driven by an external Fe source, such as hydrothermal input.

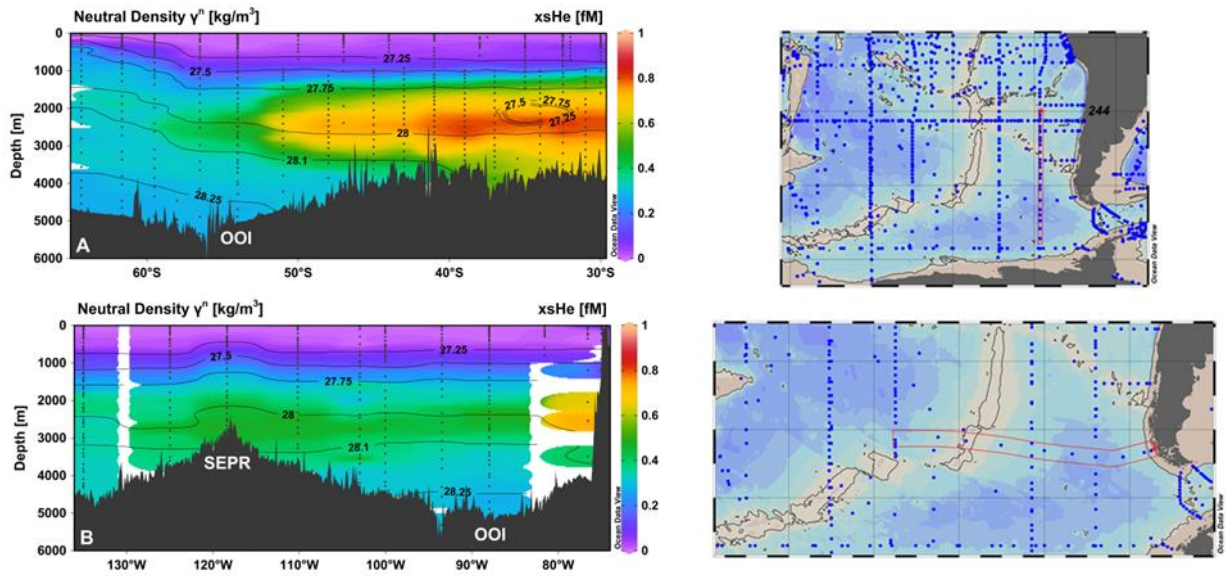


Figure S3. Section plots of excess Helium as an indicator of hydrothermal influence showing the location of our trace metal sampling station OOI. **A** A north-south transect along 88°W. **B** An east-west transect along 54°S showing the starting location for the modelled trajectories from the South East Pacific Rise (SEPR). Helium measurements are from the Jenkins et al. (2019)³ dataset.

43 **Table S2-** Trajectory modelling summary.

Source Site	Trajectory Direction	Starting Latitude Limits	Starting Longitude Limits	Starting Depth (m)	Number of Trajectories	Trajectories Started per Depth
WCR	Forward	-37.75 -38.25	-102.75 -103.25	2000-3900	10876	2000
SEPR	Forward	-53.75 -54.25	-117.75 -118.25	2000-3900	6466	2000
ECR	Forward	-39.75 -40.25	-84.75 -85.25	2000-3900	11672	2000
EM	Forward	-24.75 -25.25	-113.75 -114.25	2000-3900	7205	2000
NEPR	Forward	-44.75 -45.25	-111.75 -112.25	2000-3900	5024	2000
PAR	Forward	-59.75 -60.25	-151.75 -152.25	2000-3900	5839	2000
OOI	Backward	-53.85 -54.35	-88.85 -89.35	2000-3950	40000	1000

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46 **Table S3.** Summary of trajectory simulations used to identify possible hydrothermal source regions. The proportion of trajectories that passed within a 0.5°
47 area around the OOI site are presented relative to the number of particles that were successfully released during each simulation (Table S1). The source
48 regions that trajectories were tracked backwards in time towards were much larger than the area around station OOI, as they span along sections of the
49 ridges, allowing more trajectories to pass into the source regions in the backward-tracking simulations (Table S1 and S2).

Experiment type	Trajectory starting point	Observed signal	Ridge depth (m)	Trajectory seeding depth range (m)	No. of trajectories passing near observed signal	Proportion of release (%)	Median first passage time (years from start)
Forward	ECR	OOI	3900	3400-3900	0	0	>20
Forward	WCR	OOI	3900	3400-3900	0	0	>20
Forward	SEPR	OOI	3000	2500-3000	612	9.5	9.8
Forward	NEPR	OOI	3200	2700-3200	14	0.3	17.9
Forward	PARS	OOI	2800	2300-2800	50	0.9	15.1
Experiment type	Trajectory starting point	Source region	Ridge depth (m)	Plume source depth range (m)	Trajectories passing into source region	Proportion of release (%)	Median first passage time (years from start)
Backward	OOI	ECR/WCR	3900	3400-3900	0	0	>20
Backward	OOI	SEPR	3000	2500-3000	8278	20.7	11.8
Backward	OOI	NEPR	3200	2700-3200	515	1.3	14.4
Backward	OOI	PARN	3000	2500-3000	8105	20.3	12.7
Backward	OOI	PARS	2800	2300-2800	3074	7.7	14.4

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Table S4 – Source region limits along the Southern Ocean and South Pacific ridge systems used for backwards trajectories.

Source Region	Latitude (°N)	Longitude (°E)
CR	-41 to -36	-115 to -80
NEPR	-50 to -41	-115 to -110.5
SEPR	-57 to -49	-123 to -115
PARN	-58 to -52	-143 to -123
PARS	-64 to -55	-158 to -143

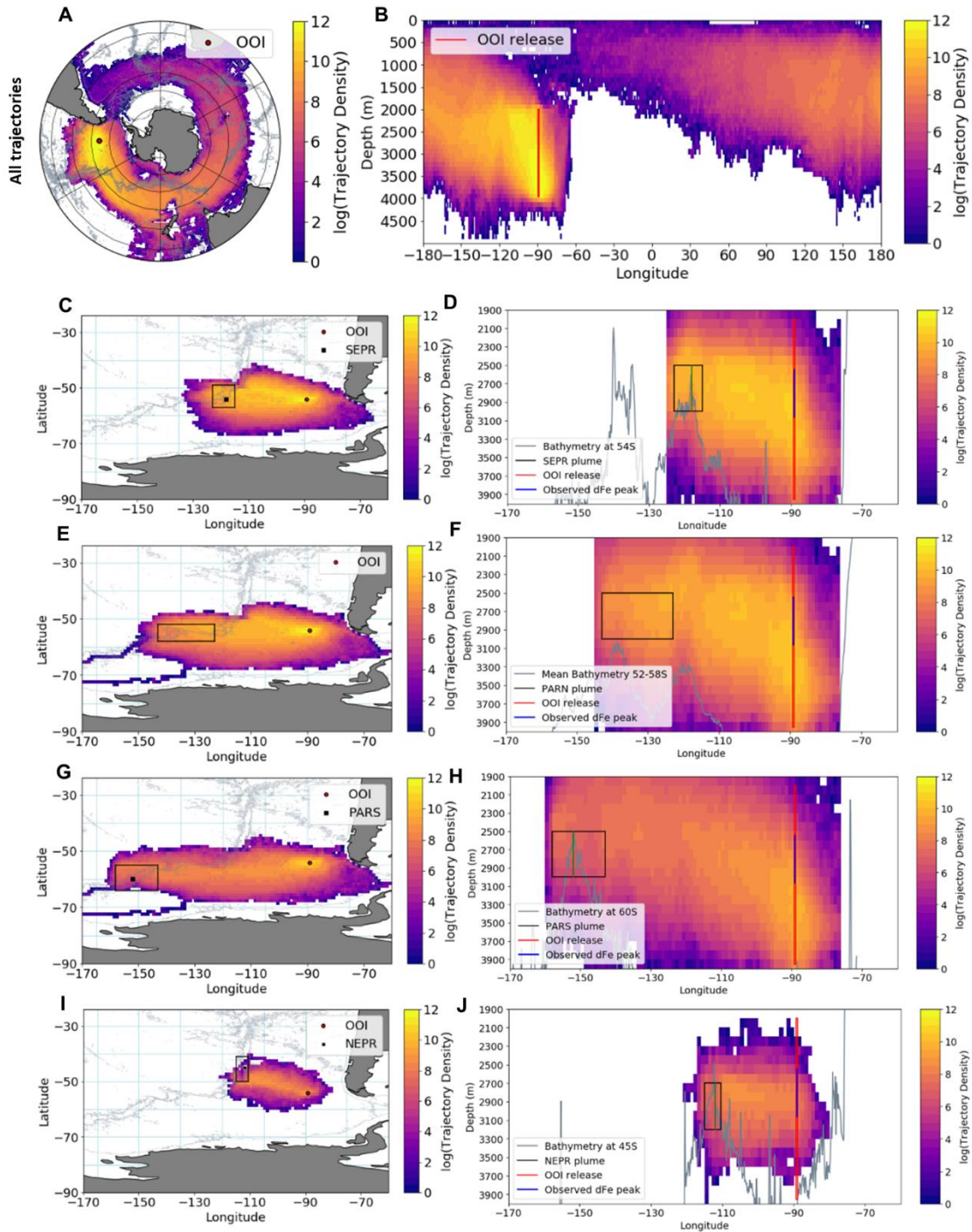


Figure S4. **A** Heatmap of all trajectories tracked backwards in time from OOI and **B** the trajectory density shown by depth and longitude. The source region plots (**C-I**) are ordered by decreased likelihood of being the dominant hydrothermal source region. Heatmaps of trajectory density for Lagrangian particles released at OOI that enter into the **C** SEPR, **E** PARN, **G** PARS and **I** NEPR plume regions (up to 500 m above forward tracking release location topography), respectively. The trajectory density of the depth evolution of the Lagrangian particles is shown for **D** SEPR, **F** PARN, **H** PARS and **J** NEPR. Note the different longitude ranges for **D**, **F**, **H** and **J**. There was not a forward tracking release from the PARN location and hence no marker is present in **E**.

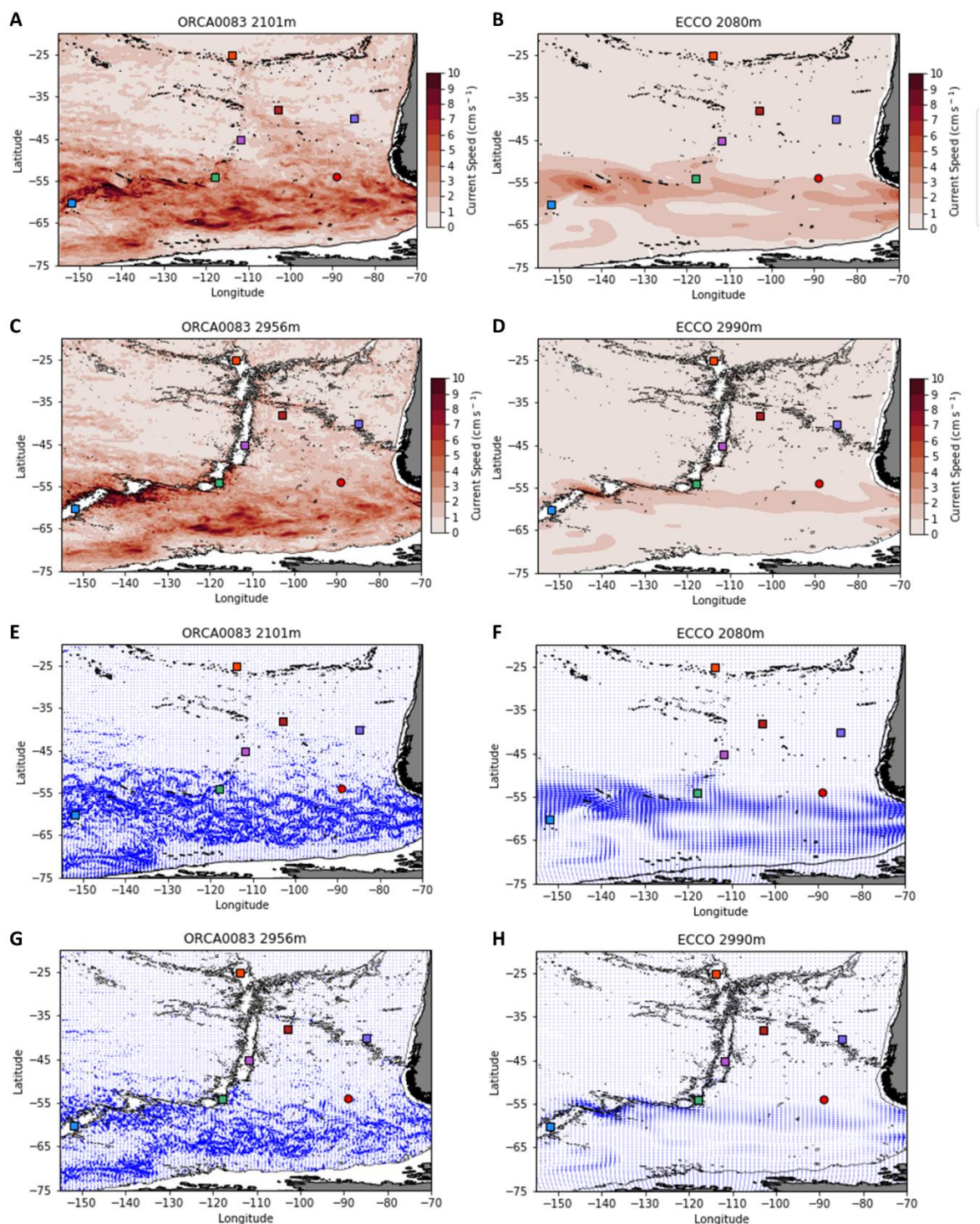


Figure S5. Annual mean current speed and vectors from the NEMO-ORCA0083 model (2101 m and 2965 m) and the ECCO state estimate (2080 m and 2990 m). The annual mean was calculated using the monthly 1/12° degree resolution NEMO-ORCA0083 model output from 2002 and monthly 1° resolution data from the ECCO state estimate from 2002. The lower spatial resolution of the ECCO estimate leads to differences in magnitude of the current speed and vectors which demonstrate the general flow is eastwards in both models. The NEMO-ORCA0083 model bathymetry is shown by a 2000m contour in A, B, E and F and by a 3000m contour in C, D, G and H. The trajectory start locations and the OOI site is shown by the coloured markers.

91 **Supplementary References**

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