RV *Southern Surveyor*

2006 program

MARINE NATIONAL FACILITY

CSIRO

voyage summary SS05/2006

SS05/2006

Mesoscale Eddies as coastal pumps: Quantifying eddy-mediated cross-shelf transport of nutrients, production and fish larvae off the WA coast

Itinerary

Departed Fremantle 1700hrs, 2 May, 2006
Returned Fremantle 1000hrs 22 May, 2006

Principal Investigator

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Scientific Objectives

Overall Objective: To quantify the cross-shelf transport of nutrients, primary production and fish larvae by eddies off the WA coast

Hypotheses

1. Warm-core and cold-core eddies forming on the coast trap water masses containing significant enrichment of nutrients, phytoplankton and fish larvae in comparison to adjacent open ocean waters

2. Once formed, both warm-core and cold-core eddies move enriched water masses offshore at a measurable rate

3. Cyclonic (cold-core) features, where present, act to upwell nutrients from the base of the Leeuwin Current

4. Eddies generally move water masses offshore over a time scale that is longer than coastal finfish larvae survive (~ one month), and thus act as oceanic predators on coastal larvae

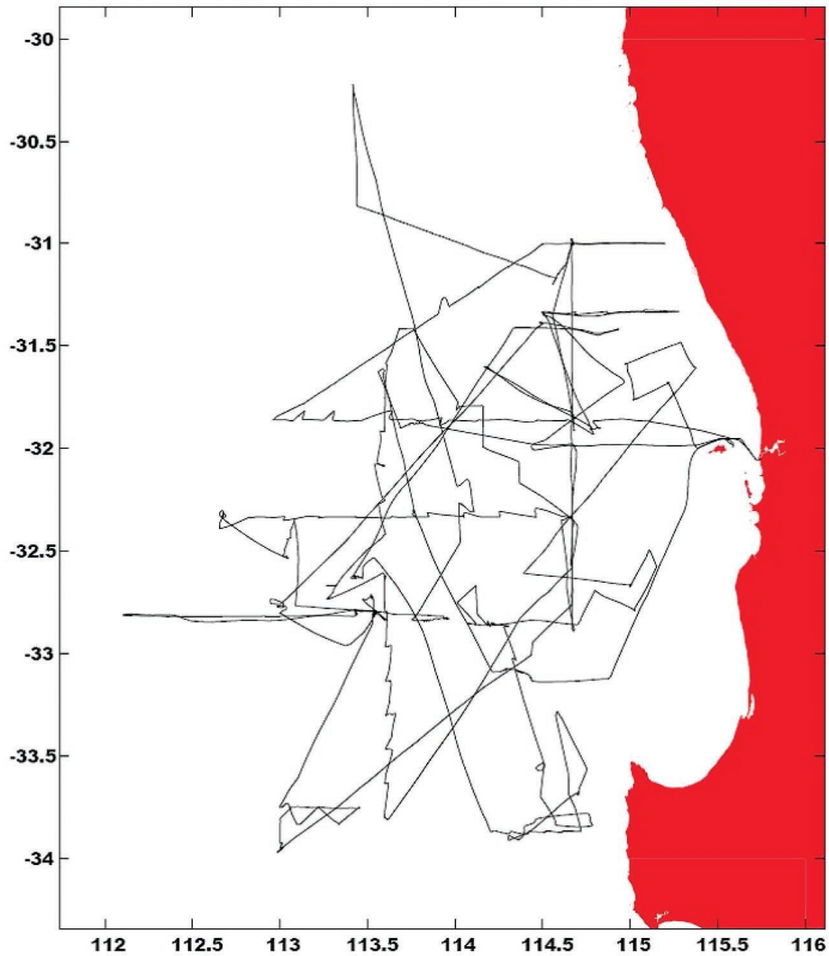
5. Eddies are generated at specific topographic locations, and organic matter in offshore sediments originates from pelagic production.

6. Eddies, meanders or filaments can enhance primary production of the region.

Voyage Objectives

1. Estimate of the fraction of coastal primary production exported to offshore waters by the large mesoscale eddy field off WA
2. Quantification of the impact of cyclonic and anti-cyclonic eddies on coastal larval productivity and/or larval trapping for key species of interest to WA fisheries (e.g. lobster phyllosoma)
3. Estimation of the contribution of the eddy field as a whole to offshore productivity.
4. Assessment of possible physical linkage between coastal and shelf sediments.

Voyage track



Results

Overall Objective: To quantify the cross-shelf transport of nutrients, primary production and fish larvae by eddies off the WA coast

Comments: While we are still in the preliminary stages of data analysis, my assessment is that we will have addressed this objective in full. This is to a large extent due to the fact that we were fully funded and given ample ship time to complete the project.

Hypotheses

1. *Warm-core and cold-core eddies forming on the coast trap water masses containing significant enrichment of nutrients, phytoplankton and fish larvae in comparison to adjacent open ocean waters*
   Our focus was on a single large warm-core eddy off Rottnest, however we did observe a forming cold-core feature to the north. Certainly for the WC eddy, this hypothesis is likely to be thoroughly proven.

2. *Once formed, both warm-core and cold-core eddies move enriched water masses offshore at a measurable rate*
   The warm-core eddy certainly moved a nutrient-enriched water mass offshore and we estimated in some detail the rate of movement.

3. *Cyclonic (cold-core) features, where present, act to upwell nutrients from the base of the Leeuwin Current*
   While our observations of forming cold-core were limited, they were consistent with local enhancement of upwelling.

4. *Eddies generally move water masses offshore over a time scale that is longer than coastal finfish larvae survive (~one month), and thus act as oceanic predators on coastal larvae*
   Our observations suggested that the actual formation time scale of the WC eddy was approximately one month, meaning that the water mass would be displaced over a significantly longer time period.

5. *Eddies are generated at specific topographic locations, and organic matter in offshore sediments originates from pelagic production*
   The sediment sampling was eliminated from the voyage plan well before departure due to the logistical complications involving the availability of personnel and equipment for this objective. Because it was not at any point considered a primary objective, we did not feel that this adversely impacted the overall outcomes of the voyage.

6. *Eddies, meanders or filaments can enhance primary production of the region*
   This hypothesis seems beyond a doubt to be true. In particular, we have observed the enrichment of the forming WC eddy with dissolved nutrients (silicate and nitrate) as well as with some strains of picoplankton and fish larvae including rock lobster phyllosoma.

Outputs:

1. Estimate of the fraction of coastal primary production exported to offshore waters by the large mesoscale eddy field off WA

Whilst our intense data analysis has only recently got underway, we fully expect to be able to make this estimate from the data we have collected. Degree of success – high

2. Quantification of the impact of cyclonic and anti-cyclonic eddies on coastal larval productivity and/or larval trapping for key species of interest to WA fisheries (e.g. lobster phyllosoma)

Whilst our intense data analysis has only recently got underway, we fully expect to be able to make this estimate from the data we have collected. We collected over 200 rock lobster phyllosoma, and have gained a small amount of funding (~20K) to analyse the genetics of these larvae to assess their biological source. In addition, we have already analysed samples from the centre of the eddy and found a wide range of finfish species. Degree of success - high

3. Estimation of the contribution of the eddy field as a whole to offshore productivity

The observed nutrient enhancement within the WC eddy make it highly likely that the eddy will contribute to offshore productivity, especially in the large size fraction (diatoms), given the silicate enrichment. The full extent of this enhancement will take more time to assess, but we fully expect to be able to do so. Degree of success - high

4. Assessment of possible physical linkage between coastal and shelf sediments

This objective was discontinued – it was decided that it was beyond the scope of the project and attempting to address this might jeopardize our ability to adequately address the other primary objectives.

Voyage Narrative

Our aim was to gain an understanding of the dynamics of large forming Leeuwin Current (LC) eddies, so for several months before the voyage we monitored satellite images closely to see if suitable features would present themselves during the period of our voyage. Before we left Fremantle, we had identified a large forming eddy off Rottnest which looked extremely promising – a significant sea surface height anomaly combined with the excursion of the LC offshore around the shoulder of the anomaly in a wide half-circle.

After a test station at SRFME station "E" north of Rottnest almost immediately after leaving Fremantle, we crossed the eddy feature E to W. We then went NE into the main body of the southward accelerating LC to deploy sediment traps with buoy "Eupompe", or "Eupo" (named after the Greek sea nymph "Good Voyage") as water mass trackers within the core of the LC and measure productivity there. Southward velocities within this core were over 1.1 m/s.

We did an extended CTD line inshore towards Lancelin to resolve the eastern boundary of the LC and our first SeaSoar leg across the gap between the eddy and the coast. The LC had taken a right-angle turn and was flowing strongly offshore south of about 31.5 S, and we SeaSoar-ed through water flowing offshore from the coast into the centre of the forming eddy. After some discussion, we decided to deploy the second sediment trap array with buoy "Pontoporeia", or "Popo" (named after the Greek sea nymph "Across the Sea") in the southern part of the developing feature, which, given the high velocities we documented (up to 1.7 m/s) started to be called the "vortex".

Tracking both buoys, with SeaSoar runs in between, we did one full production station every two days at each buoy, moving into a daily roster of sampling. We sampled production stations at night, with a consistent routine starting with CTD casts at dusk followed by intensive net sampling, including Bongo nets, Neuston nets (particularly for rock lobster and sea urchin larvae) and the EZ Net. Meanwhile, both buoys circled perfectly around the centre of the vortex at first, but on 12 May we had to retrieve Eupo, which had re-encountered southward flow to the SE at about the 500m contour, and suddenly left the vortex and began to follow the LC south. In the mean time Popo continued circling around the centre of the forming eddy.

The first SeaSoar fluorescence probe failed on SeaSoar leg 5 and then another failed on leg 7 - we decided to stop at Rottnest to pick up a replacement probe sent out from CSIRO. Luckily we had a transmissometer on the SeaSoar, kindly left on board for us by Tom Trull. The transmissometer is proving to be as good or better at tracking phytoplankton than the fluorometer, and has no surface quenching! After a brief stop at Rotto on 12 May we continued north to start a more intensive water mass characterization, beginning with coastal waters N of Fremantle and continuing south to a set of stations in waters off Mandurah. While we were there, Popo also popped out of the vortex and entered the main body LC and headed swiftly towards the shelf break. We were forced to stop sampling in southern coast waters and steam north to intercept the buoy before it grounded on the shelf. Luckily we were successful in doing this, because Eupo became unreliable after a deployment in the eddy centre and we had to retrieve it. Popo was then used to track the central water mass of the eddy for the last time series deployment of the cruise. We sampled intensively the water masses S and W of the vortex, as well as a forming cold-core feature well to the north.

Our final major effort was a 36 hour CTD cross section of the vortex from N to S using the underwater video profiler (UVP) at every station to 1000m. Our last SeaSoar legs were long, oblique runs, criss-crossing the area where the vortex was still partly attached to the main flow of the LC, before heading back into Fremantle on 26 May.

Summary

Overall, we had a very successful, though very demanding, research voyage. All our objectives were met, and with a few minor exceptions, the gear worked according to plan. We acknowledge the outstanding efforts of the Southern Surveyor Captain, officers and crew, and the special expertise and support of Drew Mills and Lindsay Pender, as well as the hydrochemists Alicia Navidad and Neale Johnston.

Personnel

Scientific Participants

Anya Waite	UWA	Chief Scientist/Day Watch Leader
Peter Thompson	CSIRO	Deputy Chief Scientist
Lynnath Beckley	Murdoch Uni	Night Watch Leader
Pru Bonham	CSIRO	Technician
Harriet Paterson	UWA	PhD Student
Moira Llabres	CSIC, Spain	PhD Student
Stephane Pesant	Villefranche, France	Visiting Scientist
David Holliday	Murdoch Uni	PhD Student
Jason Landrum	Georgia Tech	PhD Student
Marc Picheral	Villefranche, France	Technician
Lindsay Pender	CMAR	Voyage Manager / Computer Support
Drew Mills	CMAR	Electronics Support
Neale Johnston	CMAR	Hydrochemistry Support
Alicia Navidad	CMAR	Hydrochemisty Support

Marine Crew

Ian Taylor	Master
Shaun Mountney	First Mate
Rob Ferries	Second Mate
John Morton	Chief Engineer
Dave Jonker	First Engineer
Chris Heap	Second Engineer
Tony Hearne	Bosun
Russell Williams	IR
Graham McDougall	IR
Robert Stephens	IR
Joe Galvin	IR
Gerald Hogg	Chief Steward
Allan Sessions	Chief Cook
Rebecca Lee	Second Cook

Anya Waite
Chief Scientist

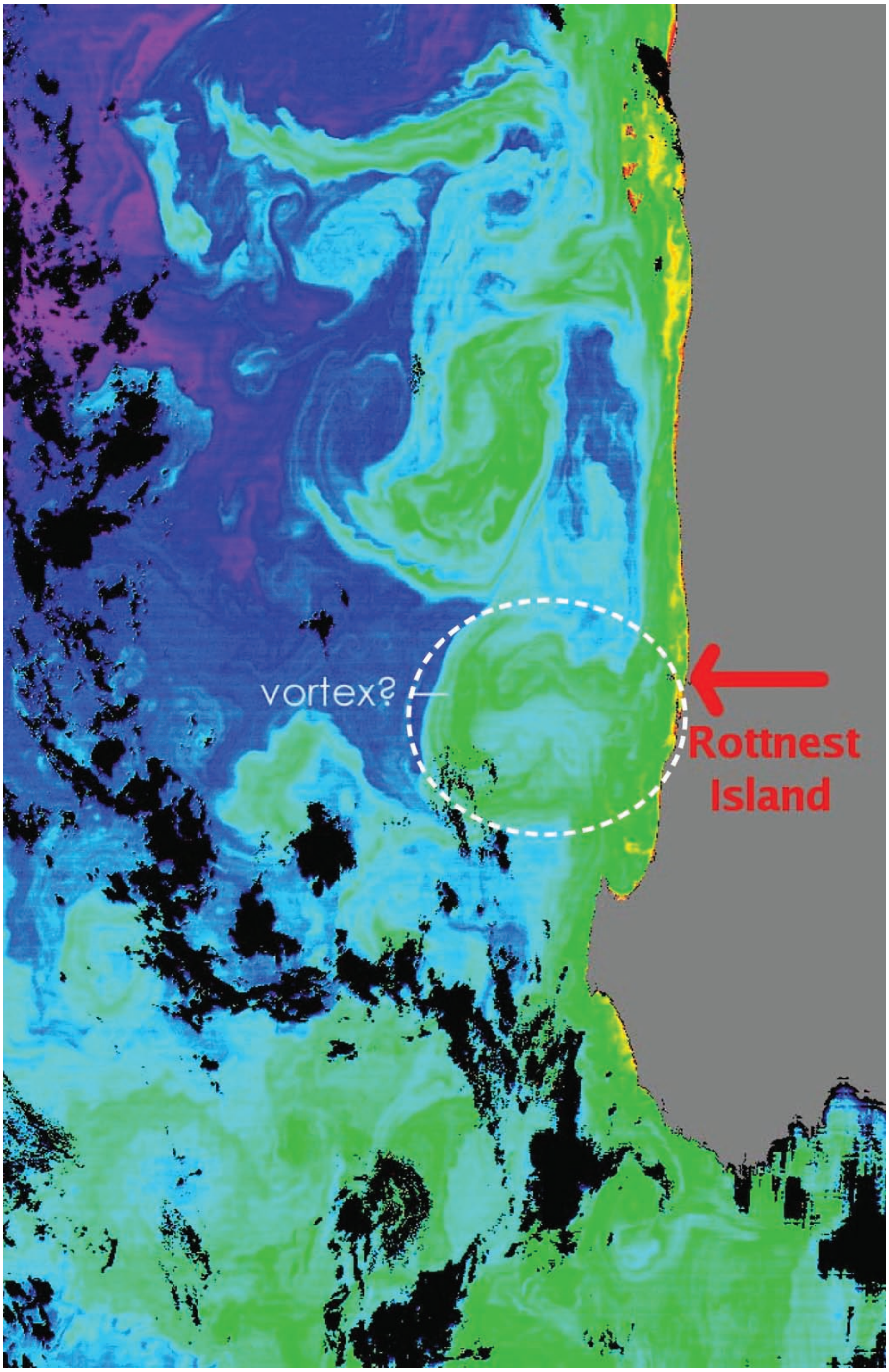


Figure 1: MODIS chlorophyll a image showing large warm-core eddy (black circle) sampled during SS05/2006.

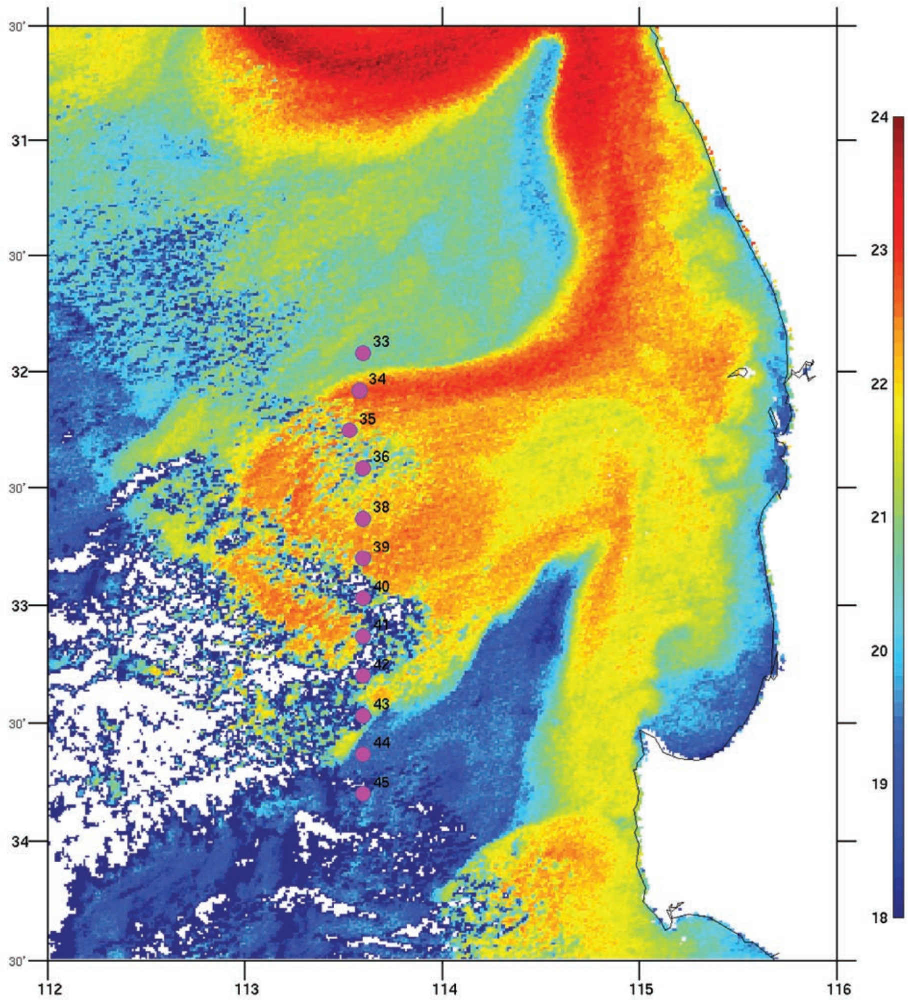


Figure 2: MODIS Sea-surface temperature image showing movement of Leeuwin current water offshore into the vortex and location of N/S CTD/UVP transect stations along 113.4 E.

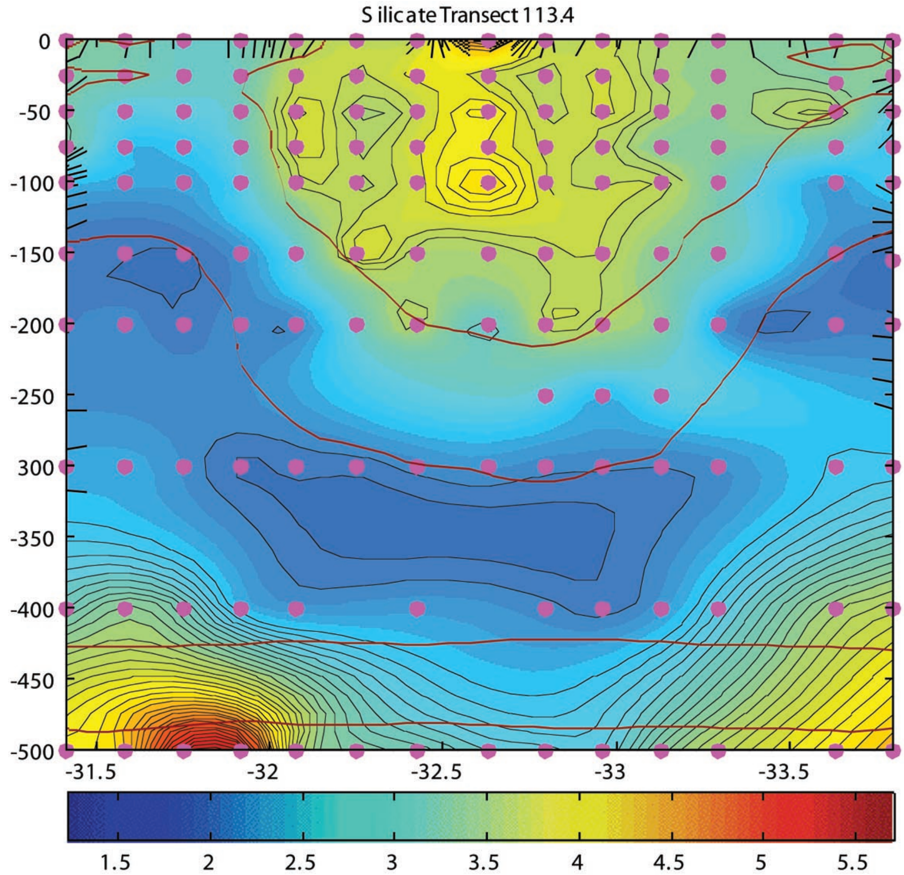


Figure 3: Silicate concentrations to 500m along 113.4 E transect (shown in Fig. 2).

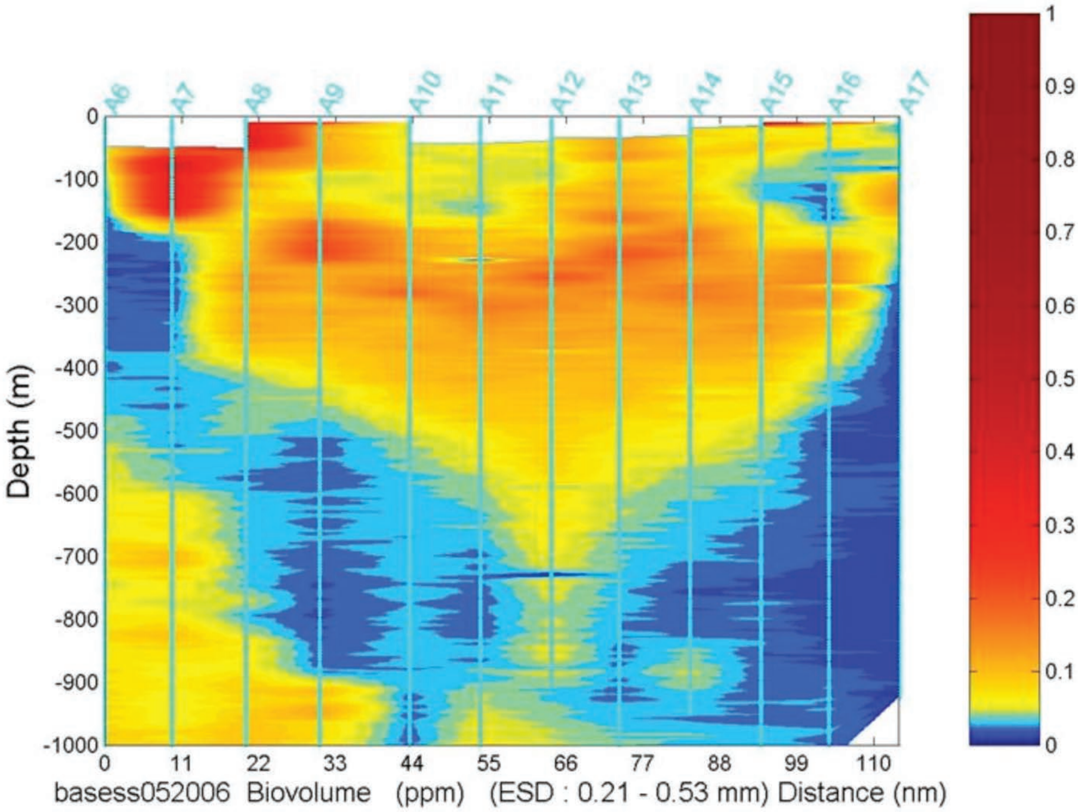


Figure 4: Particles (210 – 530 microns) concentrated within the vortex as measured along the 113.4 transect using the Underwater Video Profiler (UVP). This project was part of an international collaboration with Dr. Gaby Gorsky from the marine laboratory at Villefranche-sur-Mer, France.