

continues for 10's of Ma after crust formation (eg. Elderfield & Schultz, 1996).

Here we challenge the notion that the Sr inputs from hydrothermal circulation are either known or large enough to balance the relatively radiogenic inputs from continental runoff and groundwater flow. A simple relationship between the rate of spreading and the vigor of hydrothermal circulation has yet to be confirmed and different processes of alteration undoubtedly occur at different spreading rates, in particular at slow spreading ridges. Hydrothermal fluxes calculated by balancing the riverine inputs exceed estimates from thermal modeling of mid-ocean ridges, by up to an order of magnitude. Tracer-transport models of the Sr-isotopic evolution of seawater during hydrothermal recharge require even smaller axial hydrothermal fluxes. This problem has been recognized for some time, with low temperature exchange between the ocean crust and seawater on the flanks of mid-ocean ridges being suggested, as the source of primitive Sr needed to redress the isotopic imbalance. However, Sr-isotopic profiles from oceanic drill cores show that the upper oceanic crust has neither lost nor exchanged sufficient Sr by hydrothermal circulation at the ridge axis or flanks to explain the discrepancy between estimated fluxes and the volumes required to balance the radiogenic inputs from the continents. Recent estimates of the influence of radiogenic groundwater flow exacerbate this imbalance.

Perhaps our sampling of the ocean crust remains too poor to adequately define hydrothermal fluxes but otherwise, either riverine and groundwater budgets are seriously in error and need to be re-assessed; or there must be a large, hitherto unaccounted for supply of mantle Sr into the oceans; or the riverine flux has varied by up to an order-of-magnitude on timescales short compared with the residence time of Sr in the oceans.

OS42E-10 1610h

Short-lived Radium Isotopes in the Hawaiian Margin: Evidence for Large Fluid Fluxes Through the Puna Ridge

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Techniques to sample and measure short-lived radium isotopes have significantly advanced understanding of groundwater-seawater exchange in coastal areas. The established sampling protocol utilizes traditional wire-line samplers from surface vessels to recover large (200 L) seawater samples. These samples are subsequently passed through Mn-fiber columns at a slow rate (100 L per hour) to assure high radium stripping efficiency. But, sampling near-bottom waters in areas of complicated bathymetry represents a technical challenge for traditional wire-line water sampling equipment.

For MBARIs 2001 Hawaii expedition, we built a simple sampler to extract Ra from seawater surrounding the ROV Tiburon. The system uses a variable-flow electric pump to provide 1-2 L/min flow through one of 12 Mn-fiber-filled Ra-stripping canisters mounted on the ROV Tiburon. Values allow the flow to be directed to specific canisters. A flow meter allows the operator to control the flow and compute the volume sampled. The fibers are counted shipboard shortly after vehicle recovery.

The ROV proved to be an ideal platform for Ra-sampling because it is able to slowly pump considerable volumes of seawater through the Ra-stripping columns while maintaining close contact with the bottom. Because the manifold was mounted on the ROV's side arm, its interference with other research objectives was minimal. Most of our sampling in Hawaii was conducted as a piggyback effort. We were able to collect 167 radium samples on 37 ROV dives with an average of 206 liters of seawater passing through the stripping canisters. Moreover, we are confident that the sampled waters come from 1-3 above the bottom.

We measured significant activities of short-lived radium isotopes, ²²³Ra (half-life = 11 days) and ²²⁴Ra (half-life = 3.7 days), around the margins of the Hawaiian Islands to depths of 3100 m. These measurements suggest numerous groundwater or pore fluid inputs to the surrounding ocean. In general ²²³Ra activities were considerably greater than ²²⁴Ra in spite of the expected higher production rate of ²²⁴Ra from basalt. ²²³Ra was not supported by dissolved ²²⁷Ac. The highest enrichments of ²²³Ra were measured over the Puna Ridge (2100 m depth) east of Hawaii. Here ²²³Ra activities reached 2 dpm/100L, similar to activities measured near sites of active submarine groundwater discharge in the South Atlantic Bight. The high ²²³Ra values were not associated with significant thermal anomalies. To explain the high activities of ²²³Ra unaccompanied by ²²⁴Ra, we postulate that thermally-driven circulation of sea water through the

Puna Ridge deposits ²³¹Pa on basalt surfaces. With time the ²³¹Pa produces ²²⁷Ac and ²²³Ra, which desorbs into circulating fluids. These fluids then transport ²²³Ra into the overlying ocean. Based on the inventory of ²²³Ra above the Puna Ridge, we estimate the flow of fluids through the ridge to be on the order of 40cm³cm⁻²day⁻¹. In less than 100 years the incoming seawater could provide enough ²³¹Pa to basalt surfaces to balance the inventory of ²²³Ra above the ridge if all of the ²²³Ra was transported to the overlying water. These observations have significant implications for quantifying fluid fluxes from the flanks of the mid ocean ridge. By mapping ²²³Ra inventories in the ocean above ridge flanks and the activity of ²²³Ra in the emerging fluids, the fluid flux can be obtained. These measurements could help resolve the debate of the relative importance of high and low temperature venting from the ridge.

OS42E-11 1625h

Hydrothermal Fe and Mn at the HOT Hawaii Ocean Time Series Station

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Lupton (1998) observed a He-3 plume in water samples from stations near Hawaii at 1100m depth. He attributed this observation to the influence of the Loihi Seamount, a relatively shallow hydrothermal system at an undersea volcano that represents the future extension of the Hawaiian Islands. This plume was observed in water samples at significant distances from the hot springs, and in particular was seen in stations close to the Hawaii Ocean Time Series Station (HOT).

Quite inadvertently while investigating the oceanic distribution of Fe colloids, we measured high levels of particulate (>2 nM) and dissolved (<0.4 um) Fe at 1100 m at the HOT station in May 1998. Knowing the contamination potential of Fe, and disbelieving these results at first, we reoccupied the station in April 2001 and verified the particulate Fe maximum at this depth. Tipped off about the He-3 plume by John Edmond, we endeavored to verify the reality of this feature by measurements of Mn, which is also released by hydrothermal vents but travels further from the source than Fe and is less contamination-prone. These studies show a 0.6 nM Mn maximum at 1100 meters, verifying the potential hydrothermal source.

W.S. Moore (personal communication) suggests that this feature might be due to groundwater input from Hawaii, based on Ra isotopic evidence at this depth near the bottom. We cannot rule out this possibility, but in view of the clear He-3 signal near this site, we favor the hypothesis of a hydrothermal source for Fe and Mn.

OS51A MC: Hall D Friday 0830h

Oceanography of the Eastern Boundary Region of the Subtropical North Atlantic Gyre I (joint with B, V, PP)

Presiding: S Neuer, Arizona State University; G Parrilla, Instituto Espadol de Oceanografia

OS51A-0465 0830h POSTER

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A SubTropical Oceanic Ring of Magnitude (STORM) that budded from the Azores Current was

studied in the Eastern North Atlantic Ocean in April 1999. The cyclonic eddy, called Leticia, was centred at 32.4~N 28.7~W and extended across a scale of more than 200 km in an east-west direction. Shallowing (>50 m) of the deep chlorophyll maximum (>0.3 mg m⁻³) was observed at the eddy centre associated with vertical displacements of the isotherms (>100 m) within the photic layer. Integrated nitrate concentration over the photic layer was four-folds higher inside Leticia than at external region, however primary production rates were only slightly higher. Eddy diffusive fluxes across the nitracline explained less than 25% of the nitrate required to sustain the estimated new production. Intensive knowledge on the duration and intensity of the isopycnal doming above the euphotic layer and the residence time of the Storm eddies is needed in order to understand the significance of these mesoscale features upon the carbon and nitrogen budgets of the subtropical NE Atlantic. To this aim, a study of the interannual and seasonal variability in the generation of Storm eddies was carried out during the period 1993-1999 by using TOPEX-POSEIDON altimeter images and the operational ocean mesoscale forecasting system SOPRANE. The outcome of this study was used to quantify the contribution of Storm eddies to the photosynthetic production, as well as to the respiration rate, of particulate organic carbon in the NE Atlantic Subtropical Gyre region (20-34~N; 19-35~W).

OS51A-0466 0830h POSTER

Observations and Numerical Modeling of Eddy Generation in the Mediterranean Undercurrent

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In the frame of the European Union MAST III project CANIGO (Canary Islands Gibraltar Azores Observations), RAFOS floats were deployed in the Mediterranean undercurrent off south Portugal during the period from September 1997 to September 1998. An analysis of this Lagrangian approach complemented with results obtained with XBT probes and current meter data from the same project shows some of the major aspects of the flow associated with the undercurrent as well as the eddy activity related with it. Floats that stayed in the undercurrent featured a downstream deceleration and a steering by bottom topography. Three meddy formations at Cape St. Vincent could be isolated from the float data as well as the generation of dipolar structures in the Portimao Canyon, a feature not previously directly observed. The dynamical coupling of meddies and cyclones was observed for a considerable period of time. High-resolution modeling of the Mediterranean Outflow using a sigma-coordinate primitive equations ocean model (SCRUM) incorporating realistic topography and stratification reveals the adjustment of the salty plume while descending along the continental slope of the Gulf of Cadiz channeled by the topography. The model reproduces the generation of eddies in the two observed sites (cape and canyon) and the splitting of the outflow water into well-defined cores.

OS51A-0467 0830h POSTER

The evaluation of carbon transport by the Mediterranean outflow to the open Atlantic

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One step toward better interpretation of the role of the North Atlantic in the global carbon cycle is to understand carbon sources and sinks within this basin. The major objectives of our research in the CANIGO project (Canary Islands Azores Gibraltar Observations) were to quantify the carbon exchange through the strait of Gibraltar and the carbon flux by the Mediterranean outflow to the interior of the Atlantic Ocean, including the associated submesoscale eddies of Mediterranean water (Meddies). The total organic and total inorganic carbon (TOC and TIC respectively) exchanges through the Strait of Gibraltar where the Mediterranean outflow forms, in the Gulf of Cdiz, where it separates on

the three cores, and in the open ocean where it spreads as tongue and Meddies were studied.

Samples for TOC and TIC determinations were collected in June and September 1997, and in April 1998 in the Strait of Gibraltar (TOC and TIC), and in February 1998 in the Gulf of Cdiz (dissolved organic carbon and TIC). For estimation of carbon transport by the Mediterranean outflow and by Meddies we used data from the Gulf of Cdiz, from the northern slope of the Canary Islands (30 September to 8 October of 1995), and from sections between Africa and the Canary Islands, Canary and Madeira Islands, and Madeira Islands and Africa (January of 1997). TOC was analyzed by the high temperature combustion technique, with an acceptable error of $3 \pm 1 \mu\text{M C}$. TIC was calculated from experimental values of pH and total alkalinity with an analytical accuracy of $\pm 4 \text{ mmol kg}^{-1}$.

The dominant feature of the carbon exchange through the Strait of Gibraltar is the inflow of organic carbon to the Mediterranean Sea and the outflow of inorganic carbon from the Mediterranean. This fact allows us to classify this semi-enclosed sea as a sink of organic carbon and a source of inorganic carbon for the Atlantic Ocean. In the Gulf of Cdiz we found that the shallow core of Mediterranean outflow carries out 2 orders of magnitude less of organic carbon and twice of inorganic carbon than that which was estimated for the Mediterranean outflow on leaving the Strait of Gibraltar. In the Gulf of Cdiz entrainment increases the observed amount of carbon in the Mediterranean outflow from $1.8 \times 10^6 \text{ mol TIC s}^{-1}$ and $5.5 \times 10^4 \text{ mol TOC s}^{-1}$ at the exit of the Strait of Gibraltar, to about $8.6 \times 10^6 \text{ mol TIC s}^{-1}$ and $2.1 \times 10^5 \text{ mol TOC s}^{-1}$ on leaving the outer Gulf of Cdiz (at 23.3% and 36.2% respectively). The most intensive carbon transport occurs within the upper core, $5.9 \times 10^6 \text{ mol TIC s}^{-1}$ and $1.4 \times 10^5 \text{ mol DOC s}^{-1}$; the importance of the shallow core as a vein of carbon transit is very small.

The integrated carbon input of the Mediterranean Water to the interior of the North Atlantic is a superposition of carbon inside the Mediterranean tongue and Meddies. According to our calculations, Meddies and the Mediterranean tongue carry out as much as 1.8×10^6 and $6.8 \times 10^6 \text{ mol TIC s}^{-1}$, and 4.2×10^4 and $1.6 \times 10^5 \text{ mol DOC s}^{-1}$ respectively. The net carbon transport inside of the Mediterranean outflow to the open ocean is about $8.8 \times 10^6 \text{ mol C s}^{-1}$. Meddies carry out approximately 20% of both inorganic and organic carbon from the net carbon flux of Mediterranean water to the open Atlantic. The computational scheme given above represents only first approximations of the highly complicated carbon pathways inside the Mediterranean outflow. To refine our knowledge of the Mediterranean water and learn its role in the carbon flux, we need further studies of its biogeochemistry, geographical distribution, movement, and decay. The results presented here are only a first step in that direction.

OS51A-0468 0830h POSTER

Circulation Patterns in the Canary Basin in 1998

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Hydrological data collected during the CANIGO experiment are combined with a linear box inverse model. Conservation of physical properties allows to deduce synoptic schemes of the circulation and water masses transports in the area between Azores Islands, Canary Islands, and the Gulf of Cadiz during the spring of 1998.

The spatial coverage of the dataset gives access to the termination of the Azores current and its connection with the eastern boundary and the subtropical gyre. Mediterranean water spreading from the Gulf of Cadiz is tracked through the basin and the bottom water transport is quantified.

Furthermore, four repeated surveys near the Canary Islands allow us to examine the variability of the easternmost boundary during 1997/1998: from the surface (with the Canary Current) to the bottom water sailing around the topography.

OS51A-0469 0830h POSTER

Chlorophyll 'A' in the Northern Canary box. Retrieving of Total Chlorophyll Content From Sewifs Data.

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We have studied the performance of several empirical algorithms for the determination of chlorophyll 'a' from satellites by comparing their results to the fluorometric measurements made during four cruises carried out during CANIGO project. These campaigns encompassed all seasons to the north of the Canarian Archipelago. The in situ data set was complemented by ESTOC monthly measurements for the same period.

The comparison of satellite derived information with the surface measurements allows for the selection of the most suitable algorithm for this area. It has been also possible to establish a model for the seasonal behavior of the chlorophyll 'a' profiles and the total amount of this pigment. We have also studied the relationships between surface concentration and total columnar amount of chlorophyll 'a' and also between seawifs data and total chlorophyll content.

In view of the results of the analysis performed we established a locally enhanced method for estimating total phytoplanktonic biomass from seawifs data, together with the accuracy level and applicability conditions of this estimation. The biomass obtained from satellite together with light conditions were used to estimate the primary productivity of these oligotrophic waters.

OS51A-0470 0830h POSTER

The Cape Ghir Filament off NW Africa in Winter

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The extended upwelling filament region off Cape Ghir (Morocco) influences mesoscale current features as well as the biogeochemistry up to several hundreds of kilometers into the open ocean of the subtropical North Atlantic gyre. While traditionally the filament has been studied during the main upwelling period in summer/fall, early SeaWiFS images had shown the presence and considerable extension of the filament also in winter. In the context of the CANIGO (Canary Islands Azores Gibraltar Observations) project, we studied the hydrography and biogeochemistry of the Cape Ghir filament region during a cruise in February 1999. We examined the seaward extension and small-scale structures of the filament both by conventional bottle sampling and by small scale mapping using a towed, undulating shuttle with mounted CTD and fluorescence sensors. The sampling was guided by concurrent SeaWiFS satellite images. The satellite images showed that the seaward extension could be as far as 300 km during the investigation period, with highly variable branches that eventually merged with the ambient waters. Within the branches we found small-scale variability in temperature and pigment concentration, with pigment maxima often below the optical depth of SeaWiFS. Particle flux determined with several free-drifting traps deployed in the filament region was also very variable, but could be enhanced up to 7 times above the ambient open water values. Our study shows that the filament is a feature that is present year round and that has to be considered for the study of oceanographic processes along the NW African upwelling margin also during the non-upwelling season.

OS51A-0471 0830h POSTER

Carbon Dioxide System in the North-East Atlantic Ocean

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From 1995 the QUIMA group have been involved in the study of carbon dioxide system in the Canary Region in the North Atlantic Ocean. Two study areas are well defined in this region. One, where the ESTOC station is located, is North of Canary Archipelago, uninfluenced by the islands. The ESTOC Station (European Station for Time series in the Ocean, Canary Islands) is positioned at 2910N, 1530W, about 100 km North of the island of Gran Canaria. The other area of study is South of the islands where eddies are generated by the perturbation of the mean flow of the islands. These eddies are sequentially generated with a period ranging between several days and a few weeks with large mesoscale variations in the South Canary area. In this poster we present results obtained during four years about seasonal variability on pH, total alkalinity, inorganic carbon in the water column and pCO₂ in surface waters. We correlated these parameters with the concentration of nutrients and the hydrographic conditions. The CT seasonal variation is only 20 mmol Kg⁻¹, similar to the range found in other oligotrophic regions. A strong seasonal variability was found for fCO₂sw with an amplitude of 60-80 matm. The fCO₂sw annual cycle presents the characteristic minimum values (320 microatm) in Winter and maximum in Summer (395 microatm). The maximum outgassing rate is in August (8 mmol m⁻² d⁻¹) and the maximum rate of ingassing is in February-March (-7 mmol m⁻² d⁻¹). Southern Canary Islands, the generation of eddies and warm wakes due to island effect produce a pumping of carbon dioxide and nutrients in the area high correlated with the dynamic conditions. The variability of the carbon system parameters observed during September 98 can be explained through both the nutrient and CO₂ pumping and the induced higher productivity which decreases the partial pressure of CO₂.

OS51A-0472 0830h POSTER

Sedimentary Diatom Record in the Canary Basin (NW Africa): Coastal Productivity Overlapping HE Imprints?

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Diatoms were quantitatively studied in five sediment cores located in the Canary region. Three cores located along a productivity gradient 29N (GeoB4240, GeoB4241 and GeoB4242), and two cores (GeoB4216 and GeoB5559) from the highly productive area off Cape Ghir. Off the Canary region, coastal upwelling is the outcome of the Trade Winds seasonal variability. Given that diatoms are the major component of the phytoplankton community during upwelling events, Diatom Accumulation Rate (DAR) variability in the studied cores, are assumed to reflect changes caused by different levels of upwelling related productivity. DAR in the Canary basin (108 valves m⁻²kyr⁻¹) is in the same order of magnitude reported for Cape Blanc and one order of magnitude higher than reported for the Iberian margin. Along all but the most offshore sedimentary sequences, coincidence of high diatom accumulation values and higher abundance of spores of the upwelling related species *Chaetoceros* indicate glacial stages, as more productive than interglacial intervals. However, variability of the diatom record in a shorter time scale at the timing of Heinrich events, seems to support the idea of higher productivity attributed to nutrient input by incursions of freshwater from melting icebergs, as proposed by Kiefer et al. (1995) and Kiefer (1998) investigations in the subtropical blue ocean south of the Azores (core SU92-18) and south-west of the Canary Islands (core 15637).