

need to ask questions to make sure they are getting what you're saying. Encourage the journalist to interrupt you. And try not to appear too irritated.

Also, encourage the journalist to contact you for further information. Often, a callback is intimidating. This is especially so for me because I've witnessed the disdain that scientists hold for journalists who don't seem to get it the first time. But I'm sure most scientists would rather be bothered than have their science misrepresented. It helps to have graphics and photos ready for the journalist. Anything you can offer to the publication's art department helps ensure the accuracy of the article's accompanying graphics.

Get Excited! Explain what you do with enthusiasm. If you are bored by your work, imagine how a journalist will feel interviewing you. This summer David Kestenbaum, an AAAS fellow working for a radio station in Columbus, Ohio, interviewed an ornithologist who actually yawned on tape throughout the entire interview.

Office interviews I conducted seldom produced the excitement and enthusiasm my article might show if I'd actually been in the field with the scientist. But Seth Moran, a seismologist from the University of Washington was ready for me when I arrived in his basement office. With maps and seismographs, he excitedly explained the seismic network set up in the Cascades. He even took the time to set up a projector full of field slides.

Try Interviewing Someone Out of Your Field. In my career as a student, I've often been amazed how deeply divided different earth sciences are. Imagine interviewing someone in another Earth science field. Magnify the frustration by a factor of 10, and you've got the beginning science writer view on your work.

I've often heard scientists grumbling down the halls of academia, "But I gave them all that good science. They must be too ... to get it." Whenever a reporter uses a quote like, "This will be the big one for sure!" it's usually because the source failed to provide much that the journalist could understand and identify as newsworthy.

Deadlines. Think of the pressure you're under to turn in a meeting abstract or a grant proposal. Journalists are under this kind of pressure daily. When a journalist is covering your work, if you don't return messages promptly, the reporter will have to do the best he or she can, which may not be in the article's best interest. The publication's editor, like the folks running meetings or dishing out grant dollars, will not wait for the piece.

Granted, I've heard legitimate complaints about the overzealous reporter who sinks canines into one entirely speculative sentence in your paper's discussion section and bases the whole article around it. But overall, placing the blame for bad mainstream science reporting solely on the journalists is ignoring at least half of the problem.

Recently, I had lunch with Patrick O'Neill, an *Oregonian* health reporter. Missing my life as a journalist, I inquired about his current work. "Oh," he said, looking exhausted and leaning into his lunch plate, "I've been working on this story that I've researched to the *nth* degree....I've worked on this thing for nearly *two weeks*." Having spent the previous day with David Zimbelman, my mentor volcanologist who is into his fifth season climbing and collecting in the Cascades, I realized that scientists and journalists are not meant to act as one or even have a complete understanding of one another's work. And I realized the fundamental division between scientists and journalists: time.

My very supportive team members at *The Oregonian* regularly told me I wrote in geologic time. At some point, they said—preferably today than in a millennium—I had to give it up and let it go. After all, tomorrow would bring another day and another deadline.

Scientists and journalists will never live by the same clock, and those of us who try to bring the two together are in for a great challenge. This past year, 1997, marks the first year of AGU sponsorship in the AAAS Mass Media Science and Engineering Fellows Program. Continuing to link earth scientists to mainstream media is in the best interest of both scientists and society and the responsibility of all who have the great fortune of working to uncover the Earth's endless mysteries.

Float Experiment Studies Interocean Exchanges at the Tip of Africa

Olaf Boebel, Chris Duncombe Rae, Silvia Garzoli, Johann Lutjeharms, Phil Richardson, Tom Rossby, Claudia Schmid, and Walter Zenk

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A joint research effort is currently focused on the oceanic region south of Africa—the gateway for the exchange of mass, heat, and salt between the Indian and Atlantic Oceans (Figure 1b). The name of this collaboration, KAPEX, stands for Cape of Good Hope Experiments, Kap der guten Hoffnung Experimente, or Kaap die Goeie Hoop Eksperimente in the three languages of the participating scientists. This is the first time that scientists are us-

ing acoustically tracked floats extensively in ocean regions surrounding southern Africa to measure ocean flow patterns. At the tip of Africa, the Agulhas Current from the Indian Ocean interacts with the South Atlantic Current, contributing to the northwestward flowing Benguela Current, which transports water, heat, and salt to the subtropical and subequatorial South Atlantic (Figure 1a).

This transport increases the heat and salinity of the North Atlantic, preconditioning it for the formation of the global thermohaline circulation cell, a driving force of the world climate [Gordon *et al.*, 1992]. Our objective in the KAPEX is to trace the flow of intermediate water around southern Africa by the Agulhas, Benguela, and South Atlantic Current

systems and to answer key questions about the inter-oceanic intermediate circulation.

Message in a Bottle

We are employing more than 100 neutrally buoyant Lagrangian RAFOS floats to achieve a better understanding of the flow patterns in this key region. A RAFOS float (Figure 2) is like a high-tech message in a bottle [Rossby *et al.*, 1986]. An oversized, ~2-m-long test tube houses a microcomputer, sensors, a satellite transmitter, and a battery-pack for power. Once released from the research vessel, the instrument drifts passively along isobaric or isopycnal surfaces, depending on the float type used. During its underwater mission, the float measures and stores arrival times of coded sound signals, along with observations of pressure, temperature, and, in some cases, oxygen. The salinity of the surrounding water can later be derived from these data [Boebel *et al.*, 1997]. At the end of the mission, which lasts up to two years, the float releases a drop weight and returns to the sea surface, where it transmits the collected data through a satellite link.

The instrument's underwater trajectory is calculated, using standard navigational methods, from the sound signal arrival times. For this purpose, we have installed an acoustic

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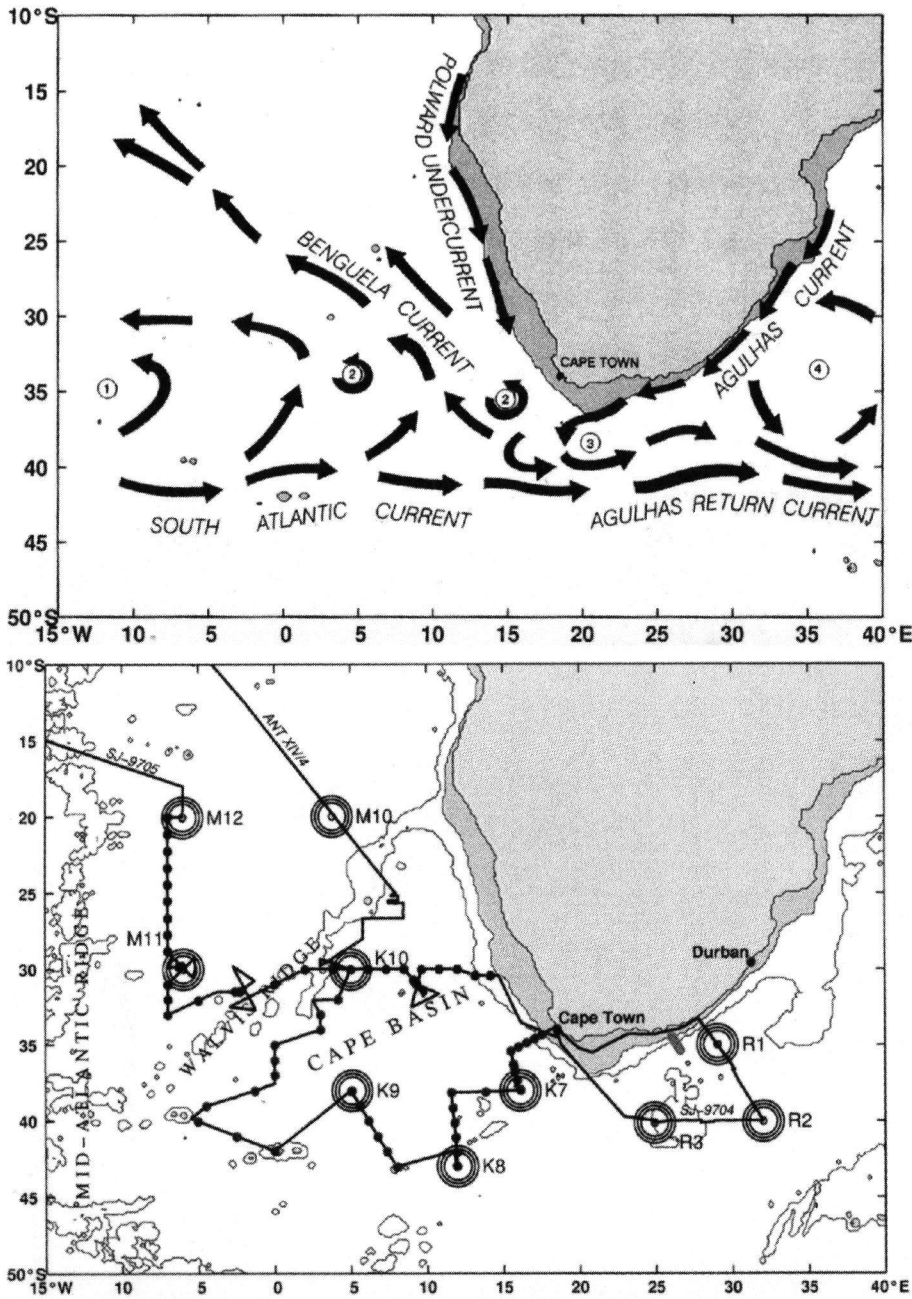


Fig. 1. a) (top) A conceptual diagram of intermediate flow in the South Atlantic and around southern Africa [Shannon and Nelson, 1996; Reid, 1989; and others]. The African continent is yellow, and the 1,000-m isobath green. Suggested paths of the Agulhas, Benguela, and South Atlantic Currents and of a presumed poleward undercurrent are indicated by solid arrows. Anticyclonic features are indicated by circled numbers (from left to right): 1. The South Atlantic Subtropical Gyre; 2. Agulhas Rings adrift in the Cape Basin; 3. The Agulhas Retroflexion; 4. The South West Indian Ocean sub-gyre; b) (bottom) The experimental design of the KAPEX. RAFOS float launch positions of the Benguela Current Experiment and the South Atlantic Current Experiment are indicated by blue and red dots, respectively. The planned float launch positions of the Agulhas Current Experiment are indicated by a green line. The sound source positions are indicated by three concentric blue circles. The 1,000-m and 3,000-m isobaths are indicated by solid lines with additional green for the 1,000-m isobath and yellow for the land. Original color image appears at the back of this volume.

navigation system around southern Africa consisting of 10 moored sound sources during 1997 (Figure 1b). The recent float-launch cruises in the eastern South Atlantic obtained full conductivity-temperature-depth profile

(CTD) and Acoustic Doppler Current Profiler (ADCP) sections. The CTD surveys provide estimates of the geostrophic shear, which will be combined with the float data to estimate transports. The CTD observations taken at the

float launch sites are also used to infer the origin of the intermediate water associated with each float.

To estimate the amount of Indian Ocean water flowing into the Cape Basin, the transport of the Agulhas Current will be monitored during the course of the experiment by repeatedly deploying a Lagrangian profiler, called POGO, across the Agulhas Current. Total transport will be estimated from the displacement measured between the POGO launch and recovery positions.

The following sections on individual projects describe specific research questions and the approach agreed upon by the participants at the recent World Ocean Circulation Experiment (WOCE) South Atlantic Workshop, held in June 1997 in Brest, France.

The Agulhas Current

The Agulhas Current, flowing southwestward along the east African coastline, is the western boundary current of the South Indian Ocean (Figure 1a). This current extends from the Mozambique Channel to the Cape of Good Hope, with surface speeds of up to 2 m s^{-1} . Usually, the current is most pronounced along the 200-m isobath, but its position deviates substantially during the passage of large downstream propagating meanders called Natal Pulses. The depth of the Agulhas Current increases downstream to more than 2,000 m in order to balance the increase in planetary vorticity. Once it has passed the Agulhas Bank, the Agulhas Current turns back on itself, forming the Agulhas Return Current. Many recent research cruises and modelling efforts have focused on the Agulhas leakage, or the transport of water from the Indian Ocean into the South Atlantic Ocean.

The inter-ocean exchange involves a variety of convoluted flow patterns, including Agulhas rings—large pulses of warm, salty Indian Ocean water in the form of anticyclonic eddies that enter the Atlantic directly south of the Cape of Good Hope. Agulhas rings, shed by the occlusion of the Agulhas Current at its turning back, are the major mechanisms by which water from the Indian Ocean enters the South Atlantic [van Ballegooyen *et al.*, 1994; Lutjeharms, 1996]. Using concurrent expendable bathythermograph (XBT) surveys supported by satellite altimetry, we have detected several Agulhas rings. We will study their size, shape, and velocity structure using the CTD and ADCP data and data from floats launched in and around these rings.

Depending on their translational speed and size, the rings probably reach as deep as 1,100 m, including the Antarctic Intermediate Water (AAIW) layer, which is found at mid-depth (between 600 m and 1,200 m) in the southern hemisphere. An estimated two to nine rings form each year [Duncombe Rae *et al.*, 1996; Goñi *et al.*, 1997] and each contribute an

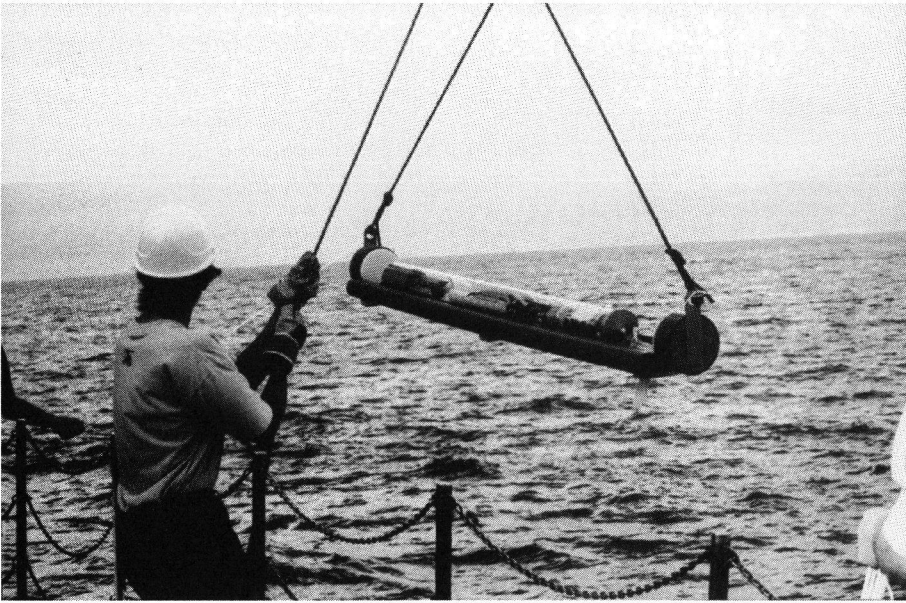


Fig. 2. Claudia Schmid, coauthor from IfM-Kiel, is launching a RAFOS float. The glass pressure housing holding the RAFOS electronics is lowered in a cradle to the sea surface. There the cradle rotates due to off-center buoyancy, thereby releasing the instrument gently into the water (photograph courtesy of R. Berger, IfM-Kiel). Original color image appears at the back of this volume.

estimated $1 \times 10^6 \text{ m}^3 \text{ s}^{-1}$ of Agulhas water to the Benguela Current. Agulhas rings transport AAIW that stems from both the subtropical Indian Ocean [Shannon and Nelson, 1996] and from an extension of the deep South Atlantic Current. This current penetrates into the Indian Ocean where it feeds into the Agulhas Current via the South West Indian Ocean sub-gyre (Figure 1a). Contrary to conventional thinking, the greatest source of water for the Agulhas Current is recirculation in the South West Indian Ocean sub-gyre and not the Mozambique or East Madagascar Currents [Stramma and Lutjeharms, 1997]. This inflow has not been located, and moreover, how the current is enhanced along-flow is unclear. In addition, further questions concern the transport mechanisms: To what depth does an Agulhas ring trap the underlying water masses? Are the dynamics of the deeper levels completely detached from the surface features? How much intermediate water is transported by a ring?

The Agulhas component of KAPEX is being carried out by the University of Rhode Island, the University of Cape Town, and Sea Fisheries Research Institute. The field work started with the RV *Seward Johnson* cruise in August 1997, which was dedicated to deploying the eastern sound sources (Figure 1b, R1-R3). Starting in December 1997, regular cruises across the Agulhas Current off Port Elizabeth (green line in Figure 1b), will be used for staggered RAFOS deployments. During each of three scheduled cruises onboard the SA *Kuswag*, we will launch 15 floats on two density surfaces. In addition to the standard pressure and temperature sensors, these floats will also feature oxygen sensors, a nov-

elty in the RAFOS technology. Monitoring the Agulhas Current transport via float deployment as well as POGO transport meters will reveal Agulhas Current transport variability. The observed variability will then be used with the RAFOS trajectories to estimate transport of the inter-ocean exchange. Some of

the floats placed in the Agulhas Current are likely to be trapped in Agulhas rings as they form at the Agulhas retroflexion (where the current turns back on itself). Other floats that become part of the recirculation will describe the South West Indian Ocean sub-gyre in a Lagrangian manner for the first time.

The South Atlantic Current

The near surface South Atlantic Current (SAC), that flows eastward across the Atlantic at approximately 40°S , near or at the Subtropical Convergence, represents the southern rim of the subtropical gyre. Recent Lagrangian velocity measurements in the western south Atlantic suggest that this flow pattern extends to intermediate depth [Boebel et al., 1997]. The deep SAC feeds into the Cape Basin from the southwest after crossing the Mid-Atlantic Ridge. Close to the prime meridian, the SAC probably bifurcates [Garzoli and Gordon, 1996] into eastward and northward branches. The northward branch is believed to supply the recirculation of the anticyclonic subtropical gyre, but the quantitative transport for either branch is unknown. The eastward flow passes to the south of the Cape of Good Hope at about 40°S , continuing into the Indian Ocean. There, part of the water turns north, feeding into the Agulhas Current system.

The deeper flow patterns, however, have been extrapolated from the flow of near sea-surface currents. Recent hydrographic studies

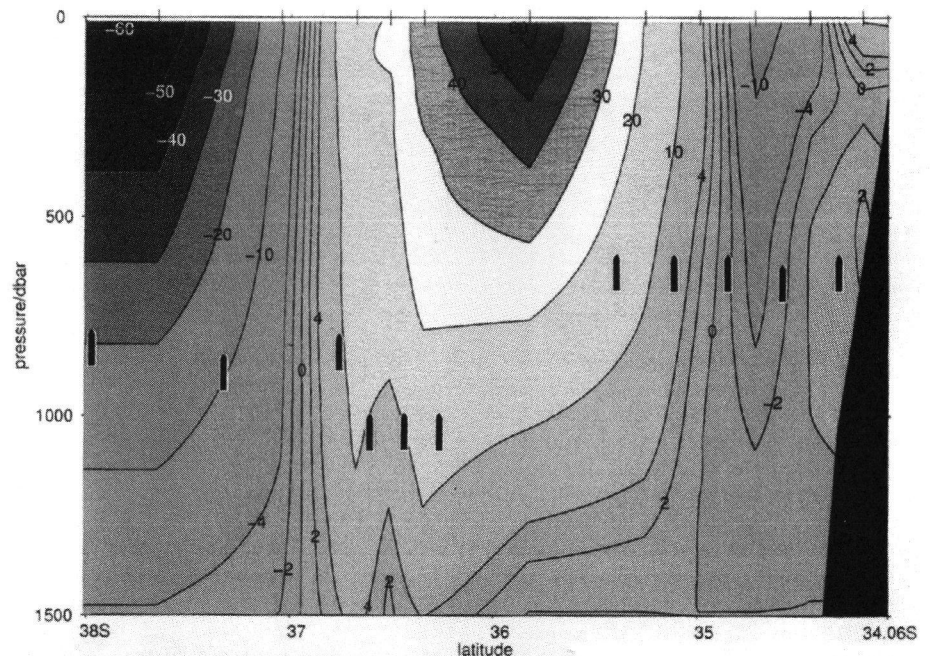


Fig. 3. Geostrophic velocity section between Cape Town and sound source mooring K7 (Note that there is a course change near 35.4°S ; see Fig. 1b). The anticyclonic feature shows velocities of up to 60 cm s^{-1} to the northwest and 60 cm s^{-1} to the east. RAFOS floats were launched at various depths (between 700 and 1,050 dbar) at positions indicated by the black float symbols. The velocity data is extrapolated linearly at the northern and southern boundaries. Original color image appears at the back of this volume.

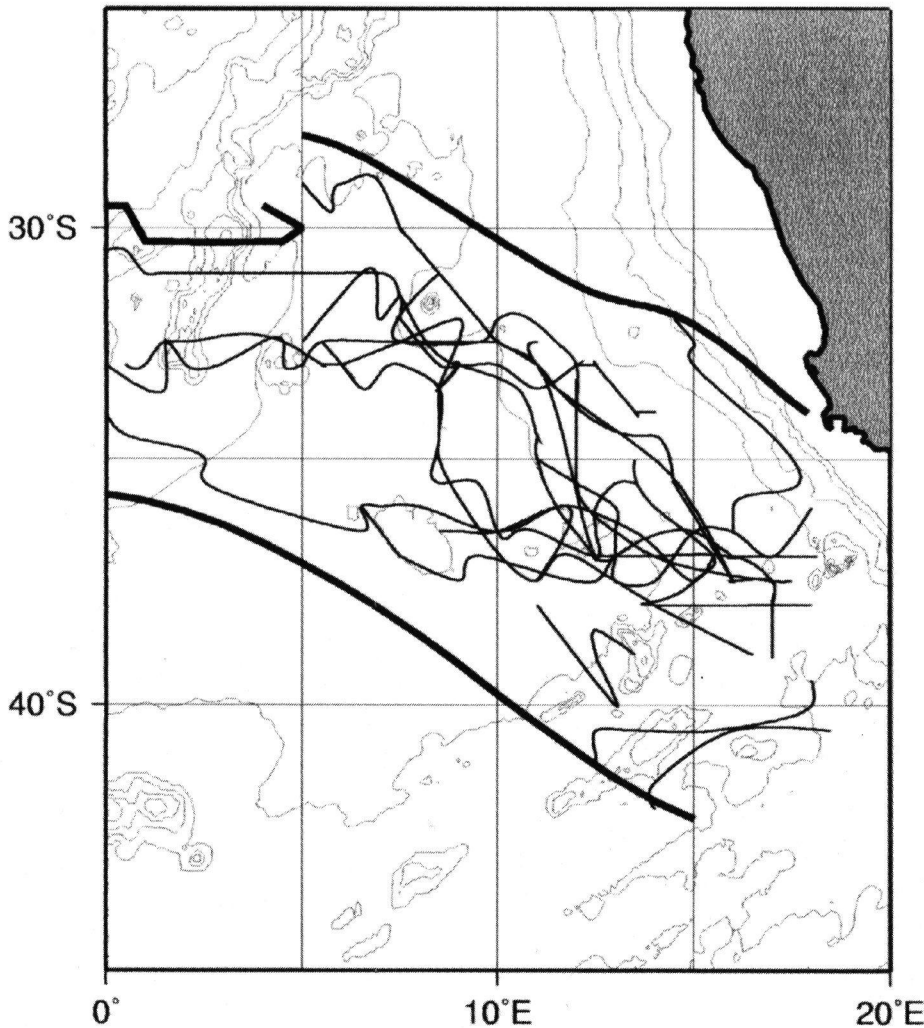


Fig. 4. Tracks of 17 anticyclonic rings formed in the Agulhas Retroflexion Region southwest of Cape Town between November 1992 and December 1995, with bathymetry superimposed. An area of increased likelihood for Agulhas rings, or ring corridor, is bound by thicker lines (adapted from Goñi *et al.* [1997]).

show that perturbations in the intensity of the AAIW salinity minimum might be related to possible annual fluctuations in the inter-ocean exchange [Boebel *et al.*, 1997]. Nevertheless, this and other questions regarding the eastern closure of the subtropical gyre still await their resolution: Is the main northward flow of SAC intermediate water found west or east of Walvis Ridge? Is it part of the Benguela Current, or should it be viewed as a separate band of flow? To what degree does the import of Agulhas water modulate the properties of the SAC water?

During the FS *Polarstern* cruise in March–April 1997, members of the University of Cape Town and the Institut für Meereskunde, Kiel (IfM-Kiel), deployed four moorings to form the Cape Basin sound source array (Figure 1b, K7–K10), plus an additional mooring in the Angola Basin (M10). We released a total of 35 RAFOS floats (red dots in Figure 1b) to drift at intermediate depth between 600 and 1,050 dbar. The floats were designed for underwater missions with an average dura-

tion of 1.5 years. We carried out CTD profiles at each float launch site and dropped XBT instruments about every 10 nautical miles. (Please visit the WWW page <http://triton.sea.uct.ac.za/sacex.htm> for a complete cruise report).

The cruise track was designed to capture the major pathways of intermediate water in this area. The southwestward leg, departing from Cape Town toward mooring K7 (Figure 1b), should give a measure of the inter-oceanic transport of AAIW—the inflow from the southeast. The concurrent XBT survey identified a young Agulhas ring (Figure 3). Information provided by a ship-borne ADCP on the corresponding near-surface (50-m to 200-m) currents supported this interpretation.

We readily detected the deeper intermediate water of Indian Ocean origin underneath the Agulhas water by its higher salinity at the vertical salinity minimum, which demonstrates the Indian influence in this portion of the Cape Basin. To determine the further motion of the ring, a cluster of 6 floats were con-

centrated close to the presumed ring's center near 36°46'S, 15°46'E at various depths (Figure 3). In addition to resolving whether an Agulhas ring or the Agulhas Retroflexion itself has been transected, the float trajectories will provide information on mixing and advection between the contrasting intermediate waters of Atlantic Ocean and Indian Ocean origin. Continuing farther west, from K8 onward (Figure 1b), the further cruise track crossed the Subtropical Front repeatedly in a sawtooth pattern. The floats seeded during this leg are expected to establish the borderline between the presumed northward branching of the SAC and its direct eastward continuation. Finally, the floats deployed during the terminal northeastward leg will outline the northward branch and the northward extent of the SAC. Most of these floats, as well as a smaller number from those deployed in the Agulhas Current proper, should move northward as part of the Benguela Current. Transport estimates of the individual branches in conjunction with transport estimates from the western SAC will serve to determine the northward flow between the Mid-Atlantic and Walvis Ridge.

The Benguela Current

The Benguela Current is the broad northward flow adjacent to southwest Africa that forms the eastern limb of the South Atlantic subtropical gyre (Figure 1a). Its northward extension is the key conduit through which the upper waters from the South Atlantic and the Indian Oceans flow across the equator. At 30°S, the entire Benguela Current is confined between the African coast and the Walvis Ridge near the Greenwich Meridian [Garzoli and Gordon, 1996]. Bordering this current on its landward side is a coastal upwelling region that supports the local pelagic fisheries. The Benguela Current flows steadily near the continental shelf but has a transient flow due to embedded Agulhas rings in the western side of the current [Garzoli and Gordon, 1996]. In the steady part of the Benguela Current, both depth-invariant (barotropic) and depth-dependent (baroclinic) components of the flow are equally important, while in the transient part, the barotropic is dominant [Garzoli *et al.*, 1996]. Agulhas rings are known to interact occasionally with the coastal upwelling regime. A recent study showed that 50% of the mean Benguela Current transport of $13 \times 10^6 \text{ m}^3 \text{ s}^{-1}$ at 30°S between the shelf and Walvis Ridge comes from the Central Atlantic, 25% comes from the Indian Ocean, and the remainder is a blend of Agulhas Current water and tropical Atlantic water [Garzoli *et al.*, 1996]. The component of the Benguela Current derived from the South Atlantic is fairly stable. In fact, an analysis of three years of geostrophic transport indicates that the mean Benguela Current transport does not change interannually by more than 20%,

which is believed to be mostly because Agulhas rings form an integral part of the hydrographic elements southwest of the Cape of Good Hope. Rings alter the local isopycnal structure and thus affect the advective patterns. The statistical properties of this eddy field originating at the Agulhas retroflection has recently been the object of intensive studies [Lutjeharms, 1996]. The average ring diameter of maximum radial velocity is about 250 km with an associated average speed of 0.56 m s^{-1} .

After detaching from the retroflection loop and before rapidly losing their high temperature contrast with the atmosphere and embedding water masses, these energetic rings can be recognized for a limited time by satellite-borne Sea Surface Temperature (SST) observations. Their velocity structure reaches down to the AAIW level, making it possible to track their drift across the Cape Basin and beyond using RAFOS floats and to study their interaction with the bottom topography.

The pathways, velocity, transport, and variability of the Benguela Current and its extension remain poorly known at intermediate depth. The objectives of the Benguela component of KAPEX are to measure how the intermediate water flows northward and westward across the Walvis Ridge and across the Mid-Atlantic Ridge into the Western Atlantic.

The field work was recently performed by the Wood Hole Oceanographic Institution (WHOI), the National Oceanic and Atmospheric Administration Atlantic Oceanographic and Meteorological Laboratory (NOAA/AOML), the Sea Fisheries Research Institute (SFRI), and the Lamont-Doherty Earth Observatory (LDEO). In September 1997, 30 RAFOS floats, two monitoring ALFOS floats, and 11 surface drifters were deployed during an RV *Seward Johnson* cruise. The floats were seeded in and downstream of the Benguela Current (blue dots in Figure 1b) at the level of the Intermediate Water (~700 m). Along 30°S, a zonal section, which focused on the Cape Basin outflow of AAIW within the Benguela Current, spanned the area between the coast and the Walvis Ridge. This line of float deployments extended across the Walvis Ridge to 7°W, where a northward line of float launches began. This meridional float section, which was also used to deploy two additional sound sources (M11 and M12), will trace the paths of the Benguela Extension and capture the advection of post-ridge rings. Supported by satellite altimetry (Figure 4), the concurrent hydrographic survey is focusing on the location and structure of Agulhas rings. Three Agulhas rings, one east and two west of the Walvis Ridge, were found, and two floats were launched at the core of each ring, for monitoring the ring's

drift and estimating ring contributions to the transport of AAIW.

Expected Results

At the conclusion of the experiment, we expect to have gathered enough information to address a major question in contemporary oceanography: What is the inter-ocean exchange of intermediate water south of Africa, and what are the subsequent movements of this water? More specifically, we hope to:

- Obtain the first exploratory, high-resolution float trajectories and velocities at intermediate depth around southern Africa.
- Observe the pathways, flux ratios, speed, and transports of the Agulhas Current.
- Record along-track modifications of the various water masses.
- Combine geostrophic velocities from the CTD data and direct measurements of velocities from the ADCP with float data to obtain the absolute velocity field.
- Use velocity maps to compare and contrast the flow in the different parts of the study area. Combining the data sets with the other efforts in the western and equatorial South Atlantic should provide direct current estimates within the upper arm of the global ocean circulation cell.
- Determine the role of Agulhas rings and the Agulhas Current modulations in the inter-oceanic exchange, as well as possible interactions of Agulhas rings with the coastal upwelling, through case studies.
- Monitor, through altimetry and float data, the migration and evolution of Agulhas rings from their site of formation (or even upstream of it) to the deep South Atlantic after they cross the Walvis Ridge.
- Study the dynamics of ring propagation and their interaction with major topographic obstructions such as the Walvis Ridge.

This cooperation is expected to give new insights into the convoluted flow patterns and mixing processes present at intermediate depth in this key, yet poorly charted area of the world's oceans. The trajectory and velocity information inherent to Lagrangian floats provide a natural extension to the classical hydrographic approach. We hope that the combination of these data will increase our understanding of the global ocean exchange.

Acknowledgments

The dedicated work of crew and officers of the FS *Polarstern*, RV *Seward Johnson*, and SA *Kuswag* significantly contributed to the success of the field work. The excellent workmanship of the Kiel (R. Berger, C. Carlsen, and P. Meyer) and Woods Hole (P. Bouchard and J. Kemp) mooring teams made success-

ful deployments of floats and sound sources possible, even under sometimes severe weather conditions. The support of the German Bundesministerium für Bildung, Forschung und Technologie (grant no. 03F0157A), the South African Foundation for Research Development and the National Science Foundation (grant OCE-9617986 (URI) and OCE-9528574 (WHOI, LDEO, and NOAA/AOML)) are kindly acknowledged. In addition, Olaf Boebel gratefully acknowledges the support of the Alexander von Humboldt-Stiftung through a Feodor-Lynen award, enabling him to work at the University of Cape Town, South Africa.

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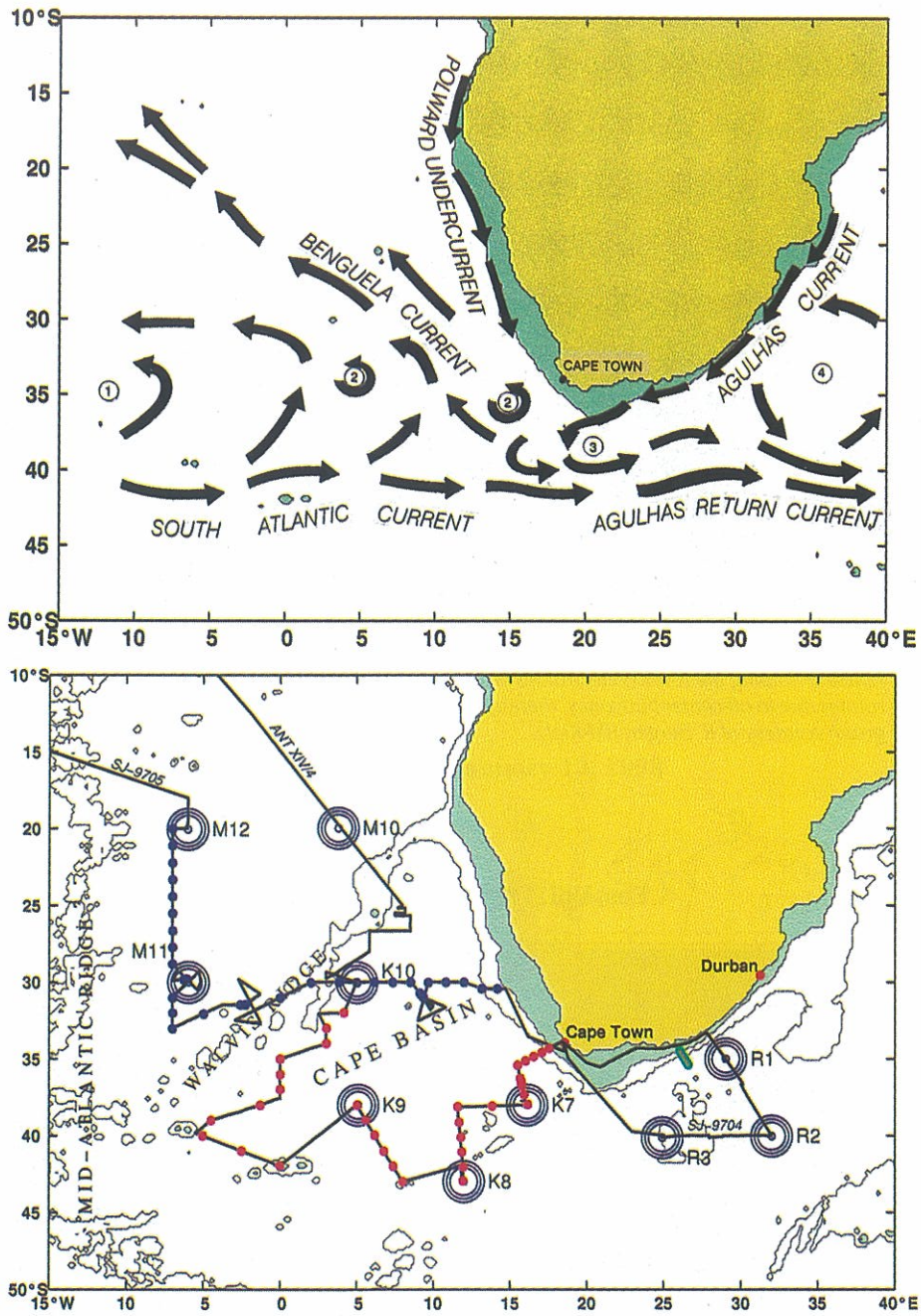


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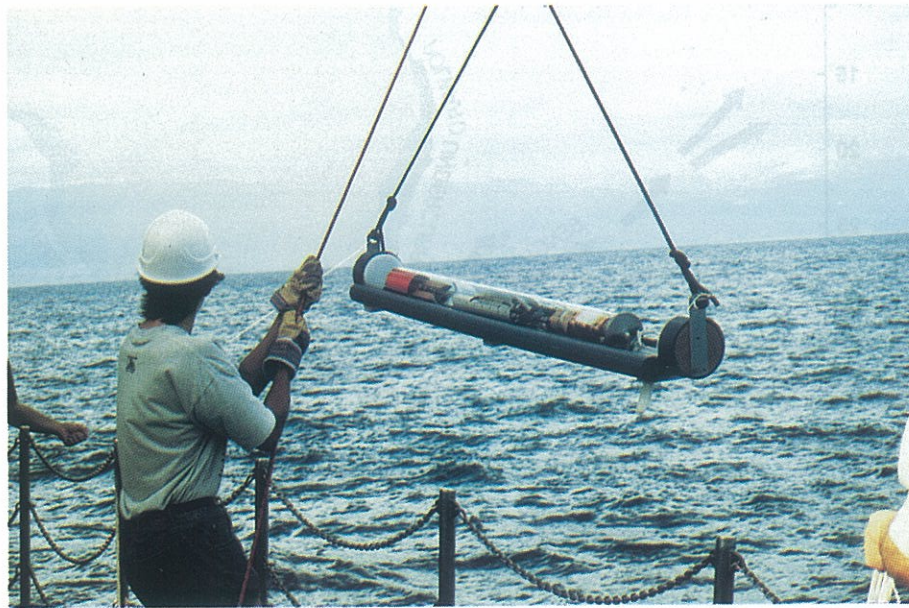


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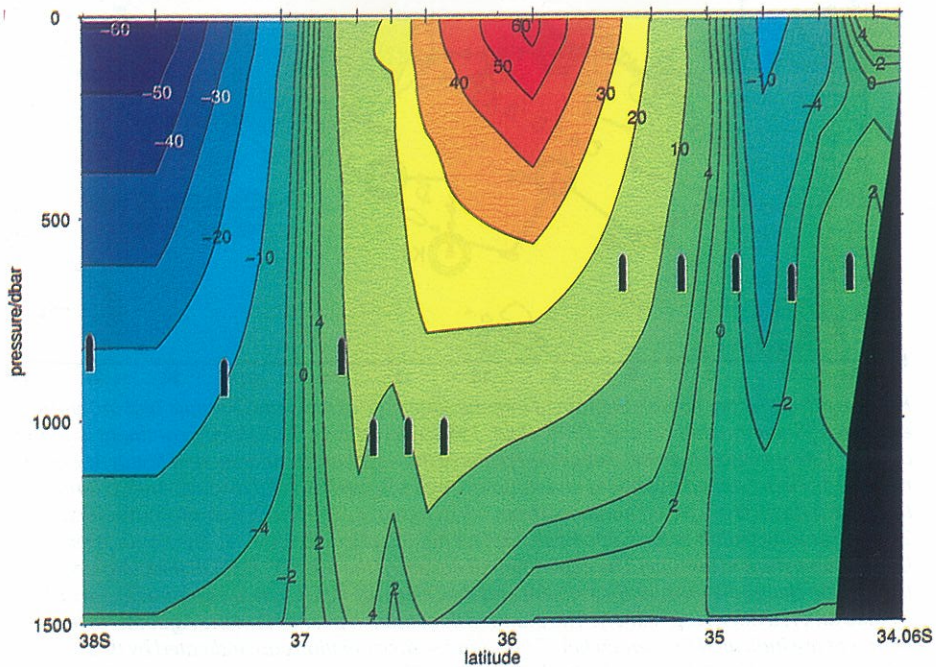


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