



*An international cooperative project
A contribution to IPY-GEOTRACES, ICED, CASO & CLIVAR-Southern Ocean*



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1. Summary of BONUS-GOODHOPE

In the framework of the International Polar Year (IPY), BONUS-GOODHOPE aims to understand the interactions between the contemporary dynamic, circulation, biogeochemistry and geochemistry in the Southern Ocean in its atlantic sector and its exchanges with the Indo-Atlantic connection on the wake of the south-Africa continental margin in the Agulhas system.

Oceanographic physicians, bio- and geo-chemists, and modellers will closely collaborate in this multidisciplinary project. Thus coupling i) the oceanic dynamics, ii) with the biogeochemistry in the water column, the atmosphere and the sediments, iii) with the study of trace elements and isotopes that are tracers of terrigenous sources, of circulation and ventilation of the water-masses, of biogeochemical processes and that can serve to quantify the particulate export fluxes to deep waters, and iv) with modelling that encompass configurations at large and regional scales, idealized and biogeochemical modelling, and simulations using trace elements and isotopes; this project will provide significant advances in the physical, chemical and biological processes taken place in the Southern Ocean and at the climatic scale. This french initiative federates about 9 French laboratories (~58 people), as well as 9 European (~22 people) and 8 International (~21 people) Laboratories. This project based on a 5 years research (2007-2011) relies on two oceanographic cruises, i) a large scale cruise (LEG1) from Capetown in South Africa to the southern frontier of the ACC (~57°S) in the Southern Ocean on board the French *RV Marion Dufresne* during the austral summer 2008 (Feb.-mid March), and ii) a meso-scale cruise (LEG2) within the Agulhas Bank ideally one year later (austral summer 2009).

BONUS-GOODHOPE has been endorsed by the International Scientific Committee *ICSU/WMO* of the IPY (*EoI#584*), and stands under three lead IPY-activities (GEOTRACES ID#269, ICED ID#417, CASO ID#132). Its objectives are also relevant to International Programs GEOTRACES (SCOR), IMBER (IGBP/SCOR) and CLIVAR/CliC/SCAR-Southern Ocean.

It will have strong interactions with the IPY ZERO&DRAKE project (*EoI#880*, PI H. de Baar, NL) which plans an IPY-GEOTRACES & CASO study along the Greenwich meridian in the atlantic Austral and through the Drake passage on board the German *RV POLARSTERN* (ANT-XXIV/3 cruise, Chief scientist: E. Fahrbach) during the austral summer in 2008. This collaborative effort will provide a



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full section between South Africa and Antarctica. Moreover BONUS-GOODHOPE will also benefit of a strong collaboration with L. Beal (RSMAS, USA) who applied to NSF to study the deep eddies formation of the North Atlantic Deep Water in the wake and within the Agulhas system.

2. Schedule of BONUS-GOODHOPE

Task	Year 1: 2007	Year 2: 2008	Year 3: 2009	Year 4: 2010	Year 5: 2011
PREPARATION & TESTS	Leg1	Leg2			
CRUISES		Leg1	Leg2		
ANALYSES		Leg1	Leg1 Leg2	Leg1 Leg2	Leg2
WORKSHOPS	Starting meeting Pre Leg1	Post Leg1 Pre Leg2	Post Leg2 Prep. of special issue Leg1	Prep. of special issue Leg2	Closing meeting
DATA BASES	Meta-file Leg1	Data Leg1 Meta-file Leg2	Data Leg 1 Data Leg2	Data Leg 1 Data Leg2	Data Leg2
MODELLING			Leg 1	Leg 2 Modelling synthesis	
WEB SITE			Project, cruises,	events, advancements	
CONFERENCES				Leg1	Leg2
PUBLICATIONS				Special issue Leg1	Special issue Leg2 Modelling

Indications of colors : green = LEG1 (large scale), purple = LEG2 (meso scale), blue = common to both LEGs.

Key-words: physics, Trace Elements and Isotopes, biogeochemistry, modelling, Southern Ocean, Agulhas System, International Polar Year, GEOTRACES, CASO, CLIVAR-SO.

3. Objectives of BONUS-GOODHOPE

Objective 1: Large scale monitoring and quantification of surface, mode and intermediate waters mass transport and ventilation in the southern hemisphere south of South Africa. Particular emphasis will be given to AAIW, SAMW and to the water properties of Agulhas rings and Cape Basin mesoscale structures. Coordination with L Beal project will also provide insight in transport of NADW via deep eddies.

Objective 2: Monitoring and quantification of meso and submesoscale cross-slope exchanges near the Agulhas Bank, with focus on Agulhas Current cyclones, and their impact on large-scale structure of water masses, tracer distribution and circulation.

Objective 3: Determination of the distributions of selected trace elements and isotopes (TEIs), evaluation of the sources and sinks of selected TEIs, and characterisation of the biogeochemical processes involved in the internal cycling of TEIs and carbon in the study area.



BONUS-GOODHOPE



INTERNATIONAL POLAR YEAR

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4. General research plan of BONUS-GOODHOPE

Our general scientific approach to fulfil the objectives is based on the coupling of i) physical oceanography ; with ii) the biogeochemistry, including nutritive trace metals (Fe, Co, Zn, Cu, Cd, and probably Mn), in the water-column, the atmosphere and the sediments ; iii) the study of selected trace elements and isotopes, in the water-column and the sediments, that are tracers of lithogenic sources, of circulation, « ageing » and ventilation of water-masses, of biogeochemical processes, and that can be used to quantify the particulate export fluxes from the surface towards the deep waters ; and iv) with the development of modellings that combine large and regional scales, idealized modelling, biogeochemical modelling, and simulations of trace elements and isotopes (Figure 1).

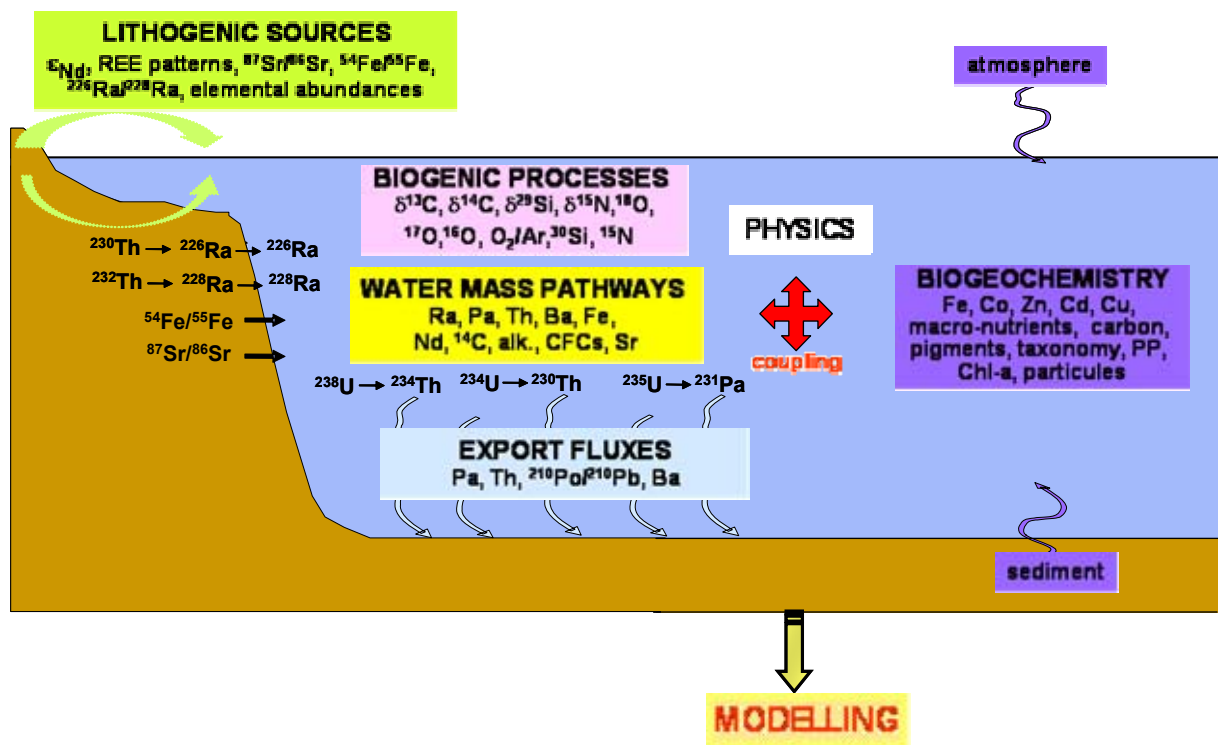


Figure 1- Scientific approach of the BONUS-GOODHOPE project

5. Oceanographic cruises of BONUS-GOODHOPE

According to differences in the sampling, its time consumption and the analytical resolution/performance for the several parameters, **three types of stations** are planned for both cruises: HYDROGRAPHIC stations (54 in total, 4h each), LARGE stations (20 in total, 9h each) and SUPER station (6 in total, 28 h each).

- **HYDROGRAPHIC station**: one CTD/Niskin rosette-cast (0 m-bottom, 24 depths, 4 hours), deployment of XBTs between CTD casts with increasing resolution across frontal regions, and deployment of about 20 profiling floats at 20 CTD casts position. This will constitute a physical background to evaluate water mass



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characteristics and transport that is being calibrated via hydrology, LADCP, and profiling float data and extrapolated in time and space via the altimetry and satellite surface temperature observations (TRIMM) (eg Legeais et al. 2005). Parameters: full depth hydrology (T, S, pressure, O₂) and other parameters (fluorescence, chl-a, nutrients, DIC, TA, dissolved Ba) associated to LADCP observations.

- **LARGE station:** one CTD/ Niskin rosette cast (0 m-bottom, 24 depths, 4 h) and one Go-Flo cast (0-2000 m, 12 depths, 4 h), PVM5 deployment (0-3000 m, 1 h). Parameters: CTD parameters, biological parameters (chl-a, pigments, primary production, plankton taxonomy), macro- and micro-nutrients, tracers and isotopes, particles levels, DIC, TA, pH, DOC/POC/PIC.

- **SUPER station:** one cast for *in-situ* pumps (0 m-bottom, 8-12 depths, pumping time = 3 h, cast time = 3 h, total of 6 h) + two CTD/Rosette casts (0 m-bottom, 24 depths) and one cast with multiple corer (0 m-bottom) = 8 h + two Go-Flo casts (0-2000 m and 2000 m-bottom, 12 depths each, 4 h + 8 h = total 12 h), PVM5 deployment (0-3000 m, 1 h), large volume sampling for process studies (~40 L sampled at one sampling-depth at the chl-a maximum using Go-Flo bottles, 1 h). Parameters: CTD parameters, biological parameters (chl-a, pigments, taxonomy of phytoplankton, primary production), macro- and micro-nutrients, tracers and isotopes, particles levels, sediments & core parameters, DIC, TA, pH, POC/DOC/PIC, process studies (Fe bioavailability, zooplankton feeding, Si regeneration, N uptake).

5.1. LEG1: large scale

The LEG-1 will be with a departure from and an arrival to Cape Town (Figure 2).

The hydrographic casts will be at relatively high resolution (every **20 nautical miles**, eg WOCE resolution). This makes a total of 80 stations. Additionally two deep Current Meter Pressure Inverted Sounders will also be deployed across the Polar Frontal Zone to monitor the variability of the hydrology (heat and salt content) and water mass transport. A total of 80-20 (large)-6 (super) = **54 hydrographic stations of 4 hours** each is planned, corresponding to **9 days**. Large stations will be achieved every **80 miles** so a total of 26 – 6 (super) = **20 large stations of 9 hours** each, ie **7.5 days**. Super stations will be made every ~ **240-320 miles**, thus giving a total of **6 super stations of 28 hours** each, eg, **7 days**.

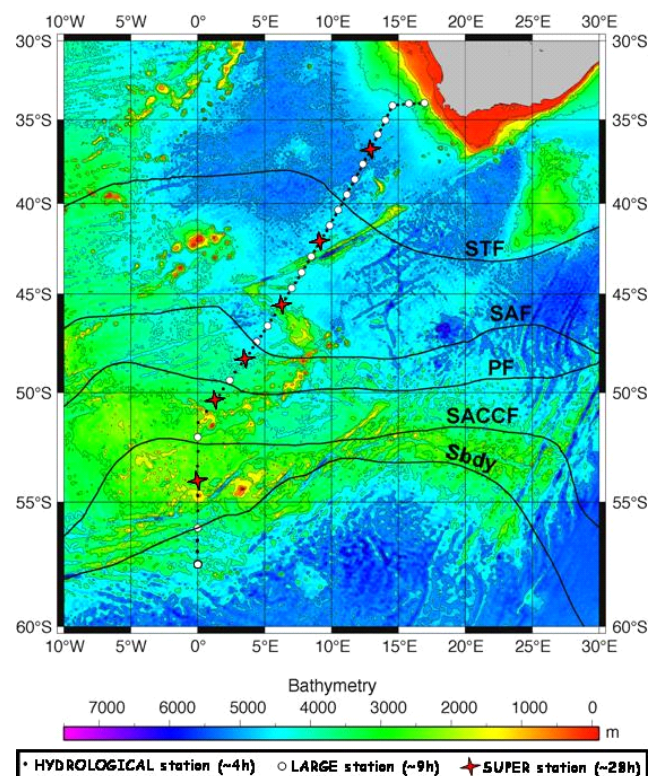


Figure 2- Sampling map of LEG-1



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5.2. LEG2: Agulhas system

The **sampling physical strategy** of LEG-2 consists of four distinct parts:

1°) A currentmeter mooring transect upstream the Agulhas Current (RC in Figure 3) in order to monitor the variability advected by the current before it reaches the Agulhas Bank. This transect extends from 27.30E; 34.20S to 27E ; 33.40S. Four currentmeter moorings will be installed for an one year duration; water and solid samples will be collected either. One mooring will be installed on the continental shelf ; composed of a 300 kHz ADCP in a lander at about 120m depth, its beams will span the whole water column upwards. A SBE25 probe will provide T and S near the bottom. The second mooring will be similar, but located on the continental slope near 450m depth and comprising a 75kHz ADCP instead of a 300 kHz ADCP. Its beams will also measure currents in the whole water column locally. The third and fourth moorings are composed of classical currentmeters (a priori Aquadopp6000's). The currentmeters on mooring 3 will be at depths 150, 400, 800, 1200, 2000m on the outer edge of the continental slope, with SBE25 probes at 250, 600, 1000 and 1600m so as to measure the internal (cyclonic shear) side of the Agulhas Current and the STSW and RSW. The currentmeters on mooring 4 will be at depths 150, 400, 600, 1200, 3000m on the abyssal plain, with SBE25 probes at 250 and 900m so as to measure the external (anticyclonic shear) side of the Agulhas Current and the STSW, SICW, AAIW and NADW. The objective is to relate fluctuations measured at this location with fluctuations (and in particular meanders and cyclonic eddies) of the Agulhas Current downstream.

These moorings will be deployed for one year; the present project is to deploy them end of 2007 or early 2008 with a South African R/V ship (chartered for 3 days) from MCM and to recover them during leg 2.

2°) Three sections perpendicular to the continental slope, to assess the evolution of the Agulhas Current proper and of its associated mesoscale features downstream – on the one hand – and the zonal differences of the shelf circulation – on the other hand. These three sections and the currentmeter transect will comprise hydrological and biogeochemistry stations to characterize the water masses, the tracers and their evolution due to entrainment, mixing, turbulence and cross-slope exchanges. High resolution is recommended on the shelf and slope to identify small-scale features such as filament, but also in the deep ocean to obtain a precise transect of the Agulhas Current, for computation of its sensitivity to barotropic and baroclinic instabilities. Therefore a 5MN resolution was chosen. Also, surface to bottom CTD and LADCP measurements will be performed at each station to determine the 3D structure of water masses and of currents and to complement the deep Lagrangian float measurements proposed by L Beal in her project. Finally, correlations of the deep structure of transverse currents with surface variability measured by satellite will be achieved. Note that en-route VM-ADCP measurements will be performed between each station, which will allow a finer correlation of deep flow with surface signals.

These three sections and the currentmeter transect will comprise hydrological and as well as biogeochemistry stations to characterize the water masses, the tracers and their evolution due to mixing, turbulence and cross-slope exchanges.

3°) Three sections along the continental slope:

(3.1) one on the continental shelf (**RS**), which will cross the Port Alfred upwelling and which will be continued much farther west to obtain a complete view of the zonal structure of the water masses and circulation on the shelf (in particular the cold ridge and the features due to the upwellings). This section will be achieved at high resolution (with a seasoar) due to the small scales of the circulation on the shelf. Technical feasibility of use of a seasoar in shallow areas is being tested by our SHOM partners. If this feasibility is not



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reachable, a glider will be used, since shelf currents are not as intense as the Agulhas Current. In particular, the cold ridge on the shelf will be crossed.

(3.2) one along the continental slope (**RM**) which will provide estimates of cross-slope exchanges at high resolution (with a seasoar). The method will associate TS and fluorimetry measurements by the Seasoar with velocity measurements by VM-ADCP. Therefore measurements will be performed as much as possible along the 400m isobath.

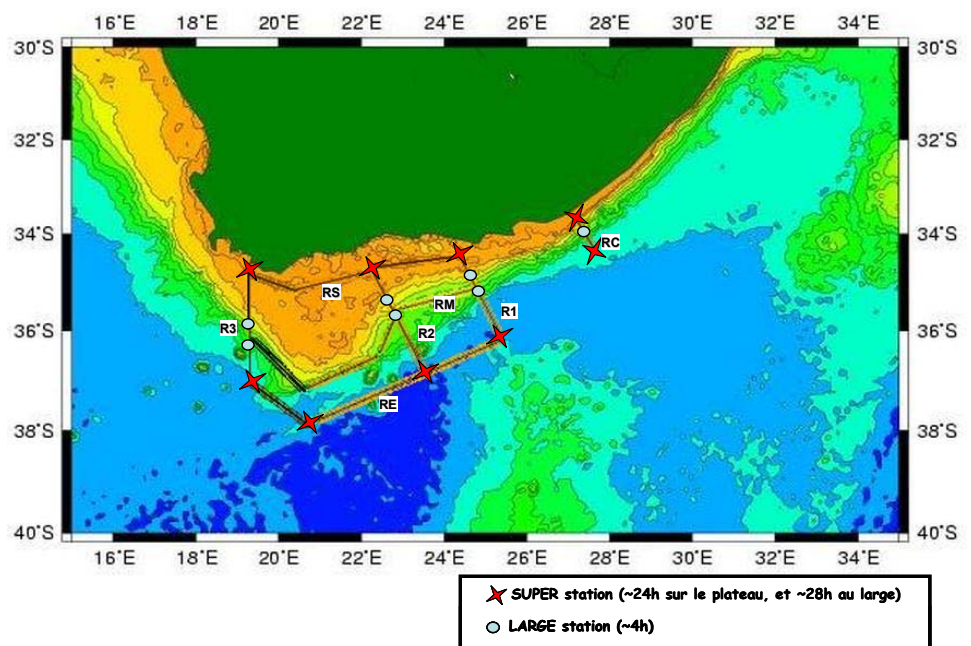
(3.3) one offshore of the Agulhas Current which will provide information on the alongstream structure of the Agulhas Current (on its southern flank) and therefore in southward turbulent fluxes (**RE**). Hydrological boxes will thus be constituted by the hydrological sections for heat, salt and tracer budgets. An inverse model will be applied to these boxes to compute the local recirculations.

4°) A focused and detailed study of a cyclone with biogeochemical measurements, fast hydrological transect (XCTD) and deployment of profiling floats and of GPS-tracked buoys drogued at subsurface (in Central Waters). Budget permitting, RAFOS floats will be bought and deployed at depths ranging from 150 to 450m to measure the eddy variability at these depths (cyclone and ring cores), using the acoustic sources deployed by L Beal.

We will also benefit from a collaboration with L Beal's project of measuring the NADW eddies south of Africa. This project was proposed to NSF. It aims at tracking NADW from the slope current west of South Africa with the help of 30 RAFOS floats (10 isopycnic, 20 isobaric) deployed at depths ranging between 2600 and 3000m. 6 sound sources will be moored in the Cape Basin and in Natal Valley to insonify both basins and the whole vicinity of the Agulhas Bank (see figure 4). These floats are supposed to be in part trapped in deep NADW eddies and to follow either the Agulhas Return Current or to drift into the Natal Valley where they may be sampled by the CTD/LADCP sections. The presence of these sound sources may be used to locate floats at shallower depths (the Beal's project shows that the SOFAR channel rises close to the surface in the Agulhas Current).

Figure 3- Sampling map of LEG-2

Specific strategy for the TEIs: in order to constrain the evolution of the distribution of the TEIs in response to the shelf input, we need to collect samples upstream from, within and downstream from the contact area (ie zonal sections) together with about 5 sediment cores (including the pore waters). In addition, the quantification of





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coast-open ocean gradients requires meridional sections. As a whole, *9 super stations* are required, identified as the red stars in Figure 3. At these stations, Niskin, Go-Flo and in situ pumps will be deployed for a complete documentation of the dissolved and particulate phases.

The strategy of LEG2 aims to help answer the main questions proposed in the previous section: what is the 3D structure of water masses on the Agulhas Bank and how can they extend towards shelf break? how do meanders and cyclones of the Agulhas Current grow? How do they, and the continental shelf features, participate in cross-slope exchanges? How do these exchanges alter the water masses along the Agulhas Bank? And finally, what are the tracer sources and distributions along the South African continental margin?

Information gathered by hydrological and LADCP stations of Leg1 will provide a complementary view of the water masses and currents on the western side of the Agulhas Bank. Also they will provide an estimate of the inflow of NADW before deep eddies of NADW are formed (they are hypothesized to form by entrainment under Agulhas rings or by instability of the slope current at the southern tip of the Agulhas Bank). Thus we will have a complete view of the surface and deep currents in the region (warm and cold routes) and the largest possible view of the (surface and deep) eddy variability associated with the boundary currents (Agulhas Current and slope current).

Sampling methodologies for LEG2

- Same as LEG1 for hydrological and tracers sampling methodologies (e.g., LARGE & SUPER stations. Voir aussi les notes importantes sur la durée des stations LARGE et SUPER).
- Currentmeter moorings: two 75 kHz ADCPs moored in antitrawling cages (pyramid shaped) with miniaturized dual acoustic releases,
- Classical moorings:
 - (a) mooring on the inner side of AC: 5 AQUADOPP6000- currenimeters at 150, 400, 800, 1200 and 2000 dbar separated by SBE25 thermistors (or equivalent) at 250, 600, 1000 and 1600 dbar,
 - (b) mooring on the outer side of AC : 4 AQUADOPP6000- currenimeters at 150, 400, 600, 1200 and 3000 dbar with SBE25 thermistors (or equivalent) at 250 and 900 dbar.

Stations description

Cruise track and stations for LEG2 are shown in Figure 3.

The schedule of LEG2 is as following:

Departure from Cape Town.

- PRELIMINARY TRANSIT towards median point of section R3 (18.50E, 36.10S) – about 120 Nq, or 12h
- SECTION Continental Margin RM with Seasoar, 360 Nq at 5 knots or 72h. End at 24.40E, 35.10S.
- TRANSIT towards the southernmost point of section RC (27.30E, 34.20S), 160 Nq, or 16h
- Currentmeter SECTION RC: One Super station (28h) at the southern point, one large station above the slope (4h), one Super station (24h) on the continental shelf, installing four currentmeter moorings (2 classical in the open ocean, two moored ADCP in anti-trawling cages on the slope and on the shelf). One CTD-LADCP station at each mooring. Total mooring time 36h (including transit).
- TRANSIT from the northernmost point of RC (27N, 33.40S) to the north of section R1 (24.15E, 34.15S): 150 Nq, or 30h with seasoar (crossing Port Alfred upwelling in its largest extent)
- SECTION R1 from North to South: 120 Nm. One Super station (28h) on the continental shelf, two large stations above the slope (2x4h), one Super station (24h) at the southern point, hydrological stations (CTD/LADCP) every 5 Nm (or 22 stations): 36h for stations, 12h for transit



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- External SECTION RE (first part from 25.15E, 36.10S to the southern point of R2: 23.30E, 36.50S): 120 Nm. Hydrological stations (CTD/LADCP) every 20 Nm (or 5 stations): 15h for stations, 12h for transit
- SECTION R2 from South to North (to 22E, 34.40N): 140 Nm. One Super station (28h) at the southern point, two large stations above the slope (2x4h), one Super station (24h) on the continental shelf, hydrological stations (CTD/LADCP) every 5 Nm (or 26 stations): 40h for stations, 14h for transit
- TRANSIT towards the north of section R1 (24.15E, 34.15S): 120 Nm, or 12h
- Seasoar SECTION RS on the continental shelf from the north of R1 to the north of R3: 480 Nm at 6 knots, or 80h
- SECTION R3 from (18.50E, 34.40S) to (18.50E, 37S): 140 Nm. One Super station (28h) on the continental shelf, two large stations above the slope (2x4h), one Super station (24h) at the southern point, hydrological stations (CTD/LADCP) every 5 Nm (or 26 stations): 40h for stations, 14h for transit
- End of external SECTION RE from (18.50E, 37S) to (23.30E, 36.50S): 250 Nm. Hydrological stations (CTD/LADCP) every 20 Nm (or 12 stations): 36h for stations, 12h for transit
- SPECIFIC STUDY of a CYCLONE west of section R3. 1 Super station: 28 h + XCTD casts: 30h + profiling float and buoy seeding : 12h : total 70 h
- Deploying 6 acoustic sound sources and 30 floats : 6 days (144h) – see figure 4.
- Final TRANSIT towards Cape Town: 52 h.

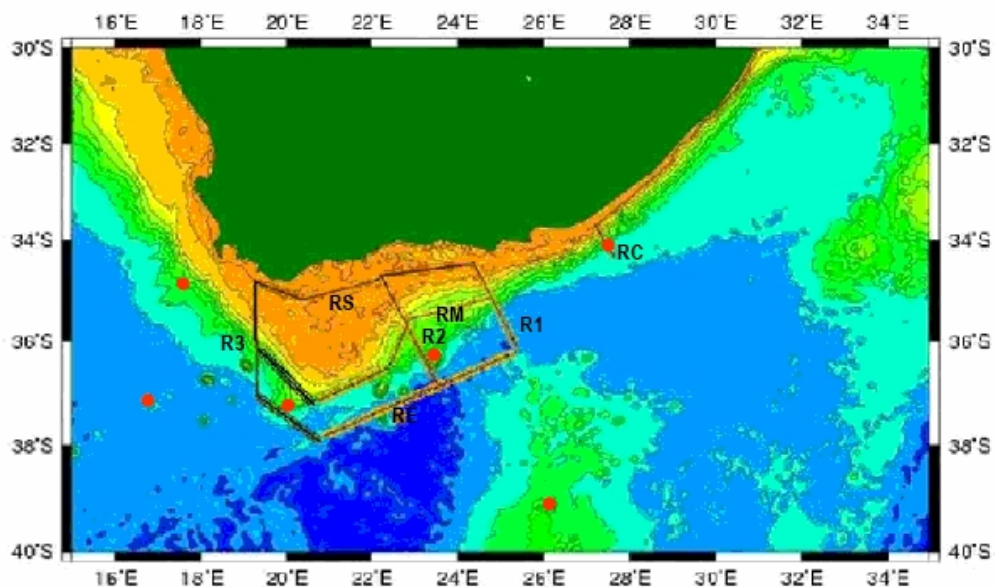


Figure 4- Position of acoustic sources (red circles) proposed by L Beal (RSMAS, Miami) to insonify the region for Rafos float deployment (positions superimposed on the hydrological network)