IFM-GEOMAR REPORT

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Leibniz-Institut für Meereswissenschaften
an der Universität Kiel

Expedition Report "Glider fleet"

Mindelo (São Vincente)
Republic of Cape Verde
05. – 19.03.2010

Berichte aus dem Leibniz-Institut
für Meereswissenschaften an der
Christian-Albrechts-Universität zu Kiel

Nr. 40
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Expedition Report “Glider fleet”

Mindelo (São Vincente)

Republic of Cape Verde

5 – 19 March, 2010

Project:

“A glider fleet to observe physical-biogeochemical coupling in the tropical ocean.”

Funded by:

Kiel Excellence Cluster "The Future Ocean"

Principal Scientist:

Prof. Dr. Torsten Kanzow

Fig. 1: Early in the morning three gliders are brought to the game fishing boat

Happy Hooker II, based in the marina of Mindelo.

1. Itinerary

The expedition went from 05 – 22 March, 2010. During this time we used the infrastructure of the Instituto Nacional de Desenvolvimento das Pescas (INDP).

Fig. 2: The main entrance of the Instituto Nacional de Desinvolvimento das Pescas in Mindelo (Sao Vicente).

2. Participants

Fig. 3: Expedition participants from left to right: Johannes Karstensen, Mario Müller, Torsten Kanzow, Andreas Funk, Gerd Krahmann, Bernd Petersen, Albert Werner.

Table 1: Expedition participants

Name	Affiliation	Task
Torsten Kanzow	IFM-GEOMAR; Kiel	Principal Scientist
Gerd Krahmann*	IFM-GEOMAR, Kiel	Glider PI & Operations
Andreas Funk	IFM-GEOMAR, Kiel	Glider Software
Mario Müller	IFM-GEOMAR, Kiel	Glider Hardware
Johannes Karstensen**	IFM-GEOMAR, Kiel	Glider Operations
Albert Werner***	GKSS, Geesthacht	learn glider operations
Bernd Peters***	GKSS, Geesthacht	learn glider operations

* 5 – 13 March; ** 12 – 19 March; 5 – 17 March

3. State of the research field

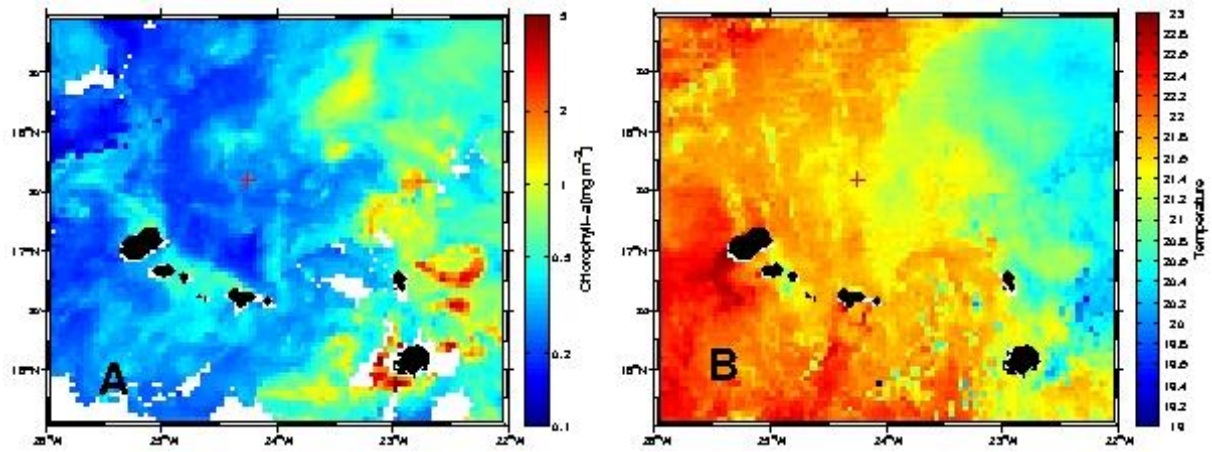

Fig.4: *Sea surface chlorophyll-a (left) and temperature (right) near the Cape Verde Islands (black) based on remote sensing (MODIS, 8-day average, 4-km grid size). The red cross denotes the TENATSO mooring site.*

Sub-mesoscale (SMS) processes represent the transition between the largely horizontal mesoscale (MS) circulation (with scales between 20 and 100 km) and the 3-dimensional finescale (0.1 - 1 km) circulation. MS and SMS processes play a fundamental role in the redistribution of heat, salt, and marine biomass, as MS eddies carry waters with different properties from their surroundings, and SMS processes act to extract properties and energy from the MS flow field and transfer them to scales where mixing occurs [1]. The SMS flow field is instrumental for the vertical transport of properties in the upper ocean, such as the upward nutrient supply to the euphotic zone [1], and for the lateral re-stratification of the surface mixed layer [2] limiting ocean–atmosphere property fluxes [3].The SMS physical forcing can lead to biological and chemical responses as time scales of SMS motions and phytoplankton growth coincide [4]. Studies aimed at SMS physical - biogeochemical coupling require high spatial resolution multi-parameter measurements [5]. In contrast to previous cost-intensive, duration-limited (and therefore scarce) measurements from research vessels, this study aims to demonstrate the potential of a fleet of six autonomous underwater gliders as multi-sensor platforms to resolve the synoptic SMS variability.

4. Scientific rationale

For the most part, physical-biogeochemical SMS coupling has been studied near ocean margins and ocean frontal systems. In contrast, we propose an open-ocean study north of Cape Verde in the vicinity of the TENATSO observatory (Fig. 1, tenatso.ifm-geomar.de), where both surface chlorophyll and temperature display pronounced SMS structures (Fig. 1). Interestingly maximum chlorophyll anomalies (near 16.7°N / 22.5°W) correspond with strong temperature gradients - a signature characteristic of SMS processes inducing vertical motion along an eddy's periphery [6]. Our objectives are (i) quantification of SMS variability of temperature (*T*), salinity (*S*), chlorophyll fluorescence (*Chl*), oxygen (O_2) and turbidity (*Tu*) in the surface mixed layer and the upper thermocline, (ii) demonstration of the coupling between physical processes (lateral and vertical advection) and biogeochemical processes (phytoplankton biomass, oxygen production/consumption, fertilization by Saharan dust), and (iii) test of different sampling strategies using a fleet of gliders. Our aims are imbedded in several central topics of the Kiel Excellence Cluster "The Future Ocean". SMS processes acting on *T* and *S* are fundamental for the stability of the large-scale circulation in a changing climate [7] which is a focus of topic A4 (Ocean Circulation Change). Processes changing biogeochemical parameters near the sea surface directly contribute to the topics A3 (CO_2 Uptake) and A6 (Marine Chemistry at the Sea Surface). Studies regarding the role of SMS activity in vertical oxygen fluxes across the upper boundary of the Oxygen Minimum Zone will be important in the context of SFB 754 "Climate Biogeochemistry Interactions in the Tropical Ocean".

5. Methods and Concepts

The SMS variability over an area of 50 x 50 km will be studied, using the fleet of gliders, as two sampling strategies will be tested (Aim 3) and single gliders are too slow-moving to resolve the synoptic variability (Davies et al., 2008). Each of the gliders will carry out 8 – 12 vertical profiles of *T, S, Chl,* O_2 and *Tu* per day along predefined tracks with a horizontal speed of 25 km per day for the duration of eight weeks. Horizontal de-correlation scales of *T, S, Chl,* O_2, and *Tu* will be computed at different depths to provide a statistical description of the SMS structures (Aim 1). Property advection will be analyzed by means of the density fields computed from *T* and *S*, and by current velocity time series from the TENATSO mooring. The physical- biogeochemical coupling (Aim 2) will be established based on both analyses of covariance between *T* / *S* and *Chl,* O_2 or *Tu* and dynamical concepts. Glider measurements of *Tu* and *Chl* will be utilized in combination with satellite-derived dust deposition and chlorophyll concentrations. Together these data will be used both to constrain the estimates of chlorophyll concentration and primary production otherwise obscured by dust and cloud signals, and to determine whether advection of nutrient rich waters or fertilization during Saharan dust deposition events contribute most to stimulating primary production in this important area of the tropical Atlantic.

6. Timetable of events

Friday, 05 March: All participants (except for JK) arrived jointly at Sao Vicente, having taken the flight connection HAM – MUN – LIS – RAI – VXE. Luggage of GK and MM failed to arrive.

Saturday, 06 March: We inspected the INDP. Container is good shape. Unfortunately no tank had been prepared for buoyancy tests (see problems). We unloaded the glider equipment, and brought it to the lab (museum) of INDP. New glider software (7.0) was installed on 3 gliders (ADD NUMBERS). See problems. Two gliders (#06, #07) had ballast bottles in the science bay installed (see problems), and vacuum tests were carried out successfully. Also, one of the gliders (ADD Number), that had the new software installed, was sent on an overnight simulation mission. Overall, the sea conditions are unpleasant, with a wave height of 3.5 m. Conditions are supposed to improve after 10 March 10. This is not a major setback, as buoyancy tests will not be possible before 08 March (Monday).

Sunday, 07 March: The simulated glider mission was stopped in the morning. One abort (relating to pitch / roll?) had occurred. It turned out to be difficult to visualize the simulated data (see problem). Therefore, an analysis of the glider mission could not be carried out. An effort was started to program a visualization tool. Software updates of the remaining 3 gliders were carried out (ADD number). Also, connection and O-rings were checked. Then, a GPS & Iridium connection test was carried out successfully with one of the gliders (ADD NR). Two gliders were sent on an overnight simulated mission.

Monday, 08 March: The two gliders successfully completed the simulation missions. We worked on visualization software (Glider_View.m) to have it cope with the new glider file format. Glider_View.m now read both the glider (engineering) and the science binary data, converts it to ascii merges both data streams into one ascii file.

Our inspection had revealed a leakage in the tank, in which the gliders are supposed to undergo the buoyancy test. Leakage was fixed. Simulations of remaining gliders carried out during the day.

Tuesday, 09 March: One of the simulating gliders (IFM09) had problems filling the air bladder. Cause was identified and removed. The tank was filled with 10 tons (2 lorry loads) of water by Justino Dios (tel. 9821082) at the cost of 5000 escudos. Buoyancy tests with all 6 gliders were carried out (see section 6.1). Programming work on the glider interface at Kiel (GK). Meeting with Bernot (Skipper) to prepare glider deployment for Thursday.

Wednesday, 10 March: Finetuning of buoyancy distribution of two gliders (IFM 07 & 10) carried out, including new ballast tests in the tank. Preparations for next day's deployment (of IFM03, 06 and 09) were taken. The gliders and equipment brought to Bernots boat in the marina of Mindelo.

Thursday, 11 March: We left Mindelo aboard Happy Hooker II at 8am, and after a stop at the fuel station, went southward along the west coast of Sao Vicente. We reached the deployment site around 10 am roughly 4 nm south of the village of Sao Pedro. The water

depth here is around 700 m. IFM06 was deployed. IFM 03 and 09 showed problems (fin, telephone connection) and were taken back to land.

Fig 5: Sea water arrives in a Justino Dios' Bedford lorry for the buoyancy tank tests.

Friday, 12 March: IFM 07, 10, and 11 were deployed (see section 7.3) at the same position as IFM06. IFM03 and 09 were tested in the lab, but the malfunctions they had displayed the day before, could not be reproduced.

Saturday, 13 March: Rough weather. IFM07 produced aborts, as it failed to call the dock server at IFM-GEOMAR. It showed a strong permantent roll at the sea surface. The course of IFM07 was altered, in order to return to the deployment site south of Sao Vicente where we plan to recover it.

Sunday, 14 March: Rough weather. Visit of Tenatso atmospheric station at Calhau. Preparations taken for a deployment of IFM03 and 09 and recovery of 07 planned for the next day. In the evening, IFM06, which had already reached the west side of Sao Antao, sent a leakage warning several times. Wolfgang's boat was hired in order to attempt to recover IFM06 the next day.

Monday, 15 March: AF, BP an AW went out with Happy Hooker II (Simon) to the deployment site south of Sao Vicente and successfully both deployed IFM03 and 09 and recovered IFM07. The attempted recovery of IFM06 by TK aboard Onda Emma (Wolfgang) failed, because of it took very long in the morning to get fuel, and the estimated time of arrival at IFM06 would have been shortly before sun set. It was decided to attempt the recovery the next day. JK led the glider control / monitoring at INDP. During the afternoon IFM06 started to operate normally again, and we steered it to the southeast, in order to shorten the recovery steam time. After return to the lab, IFM07 was re-ballasted (1kg of weight was moved downward from the ceiling to the glider based). As a consequence, the roll period was reduced by from 6.2 to 5.2 sec.

Tuesday, 16 March: AF, and AW went out on Happy Hooker II (Simon) to the usual deployment location and successfully re-deployed IFM07. Meanwhile MM and BP successfully recovered IFM06 west of Sao Antao. They arrive back in Mindelo at 19:30.

Wednesday, 17 March: AW and BP flew home in the morning. We brought the recovered glider IFM06 from Onda Emma (marina) to the INDP. There it was opened. We found small amounts of water and salt crystals in the glider interior. The traces suggested that a leak in the air bladder port had most likely caused problems. We packed our equipment and stored it in the container. An emergency recovery kit was packed for Pericles and his collegues for them to have all the equipment required to recover any of the gliders in case of an emergeny (dock server, free wave modems, etc.). AF and JK presented the emergency kit to Pericles, and explained him the procedures. Also, a visit was paid to the agent of R/V Polarstern by TK and MM, to make him aware that the equipment stored in the container at INDP will have to be transferred to R/V Polarstern by a small boat on May 03. The agent said that a tug boat would be available, and requested a loading list and invoices at least 10 days before R/V Polarstern's arrival. The 5 gliders continue to work fine

Thursday, 18 March: Last preparations for our departure were taken, together with Pericles. The 5 gliders continue to work without problems.

Friday, 19 March: Visit to R/V Islandia in the ship yard. Flight back home.

7. Laboratory Preparation of gliders

7.1 Glider boot instructions

- Prepare correct freewave box and a gliderterminal on a dockserver or a serial terminal program. Start dockserver on dockserver computer.
- Insert green plug or external power supply (remember to turn on external power supply, NEVER >15V !!!)
- The freewave should soon (5 sec) show green lights
- In the gliderterminal boot messages should appear
- Wait until "SEQUENCE: About to run initial.mi on try 0
  You have 120 seconds to interrupt sequence."
  appears. Press Ctrl-C once.
- Wait until you get a gliderdos> prompt, then
  callback 30

7.2 Hardware preparations (Mario Müller)

During the hardware checks first the missing Ballast weights were installed in IFM06 und 07. Then the batteries were connected and the plug connections were realized. Subsequently all pressure housing O-rings were greased and cleaned, and the pressure housings were closed. Finally all gliders were evacuated and the vacuum was adjusted via PC, followed by a basic system test.

IFM09 produceed a malfunction. The air bladder could only be inflated sporadically. This could be traced back to a connector problem of the magnetic valve (the isolation jacket was jammed inside the connector). Accordingly, the connector was newly soldered and the malfunction did not show up again.

Fig. 6: Mario Müller and Bernd Petersen (GKSS) adjusting the internal ballast distribution of a glider, to ensure an optimal flight behavior.

7.3 Buoyancy tests (Andreas Funk)

7.3.1 Procedure to be followed for ballasting

- Turn glider on with green plug, follow boot instructions
- put c_air_pump 0
- lab_mode on
- ballast
- wait until ballast volume 0 and battpos 0
- put c_science_on 2
- put c_science_all_on 0
- put c_science_send_all 1 (only V7.0 and up)
- lift glider into the ballast tank and attach scales
- write down sci_water_temp and sci_water_cond
- put c_science_send_all 0
- put c_science_all_on -1
- put c_science_on 0
- weigh glider
- remove wings (in saltwater it should float)
- measure 2 roll periods
- let glider come to rest
- get m_roll (aufschreiben)
- get glider out of the tank
- exit

7.3.2 Description of ballasting at INDP water tank

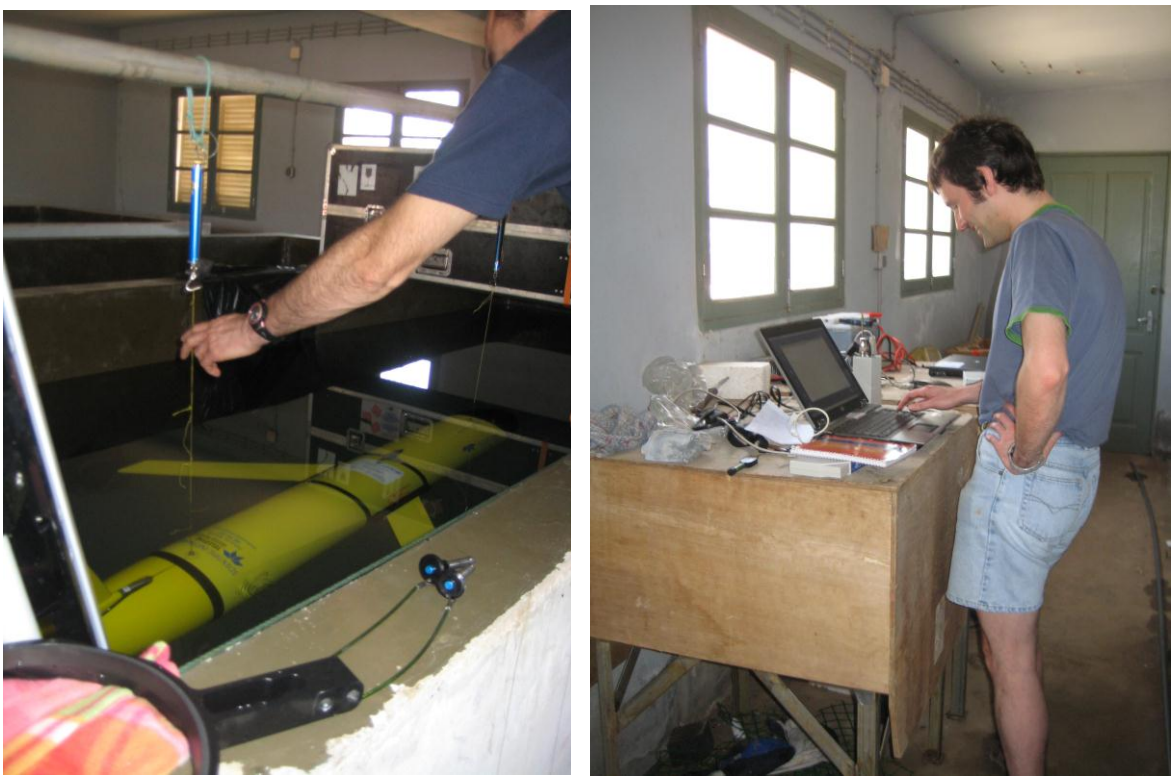

Fig. 7: Left: The buoyancy distribution of a glider is tested in a tank filled with sea water at INDP. Two scales are used with one attached to the front and the other to the rear part of the glider. Right: Andreas Funk controls the glider in the ballast mode.

Checks of glider ballasting were carried out on March 9 and 10. Prior to shipping most of the gliders had been ballasted in Kiel in a tank filled with freshwater. The gliders that had been checked in the freshwater tank and have been found to be ok in freshwater were also reasonably close to the calculated values in the salt water tank. Deviations were generally below 40g and we did not correct these differences. For some gliders the final weights had not been added in Kiel but only in Mindelo. For these gliders smaller adjustments in the balance between front and rear had to be made.

During the ballasting checks we had two cases where a glider had obviously changed the oil volume while being in the salt water tank. Gerd Krahmann found out that pitch or roll angles above 45° might lead to a deactivation of the attitude sensor and a reboot of the glider in such a way that it will pump out its full oil volume. After that we avoided such angles (by switching into ballast mode only after the glider was placed into the tank) and cross checked directly before weighing the glider that it was still in ballast mode. Conductivity and temperature of the ballast tank were measured by all gliders to see if the CTD gives plausible values. Roll angle *m_roll* and the double roll period have also been measured (the latter by using a stop watch). Acceptable values for the double roll period (i.e., two cycles) lie between 5 and 7 seconds. The roll angle should be less than 5°.

8. Open water tests & deployment of gliders

8.1 Procedures

8.1.1 Procedures before leaving land

- Prepare yoXX.ma sampleXX.ma surfacXX.ma goto_lXX.ma mission.mi
- Upload these files, type each of them to ensure proper transmission
- dellog all
- consci
- dellog all

8.1.2 On route Pre-deployment instructions

- Turn on glider with green plug and follow boot instructions.
- Make sure simul.sim does not exist. If it does, delete and exit reset
- Check mission and mafiles
- Check space on flash card
- Run status.mi
- Check iridium capability
- Check GPS
- Prepare safety buoy
- Prepare rope for glider carriage

8.1.3 Deployment instructions

To be executed during deployment. Pre-deployment has been done.

- On deck:
- Zero_ocean_pressure
- run status.mi
- let glider call after mission (you can recognize an established connection with a BAUDRATE 4800 line)
- you can now chat with the home base
- callback 30 to hang up
- check status/output of the whole mission, there must not be any noticeable problems (battery ok, vacuum 8 to 10, leak_detect 2.5)
- exit reset
- callback 30
- deploy glider with safety buoy
- upload mission and ma files
- set yoXX.ma d_target_depth to 10m
- set mission.mi no-comm timeout to 900 sec
- run mission.mi
- after surfacing download dbd, ebd, mlg, nlg files for this mission
- load data into viewer
- check different parameters (see check data card)

- if ok, repeat without safety buoy
- if that also ok
- dockzr yoXX.ma and mission.mi
- edit to 150m and 3600 sec
- repeat process

8.1.4 Check data instructions

- Download dbd, ebd, mlg, nlg files from glider
- Edit mlg and nlg files and check for errors or warnings
- Load dbd and ebd into data viewer
- Plot the following variables and see whether they make sense
- m_depth (should reach target and come back, somewhat symmetric)
- m_heading (should turn towards waypoints, if dive is long enough. Should follow c_heading)
- m_roll (should be less than +/- 4 deg, if more see whether wing gets caught by wind. Then consider taping weight to wing end)
- m_pitch (should be -25 deg down, +25 deg up and follow c_pitch)
- m_battery (should be like a full battery pack, maybe lower when pumping)
- m_de_oil_vol / m_ballast_pumped (+/- 270 or +/- 230)
- sci_water_pressure (this one is in bar !!! should be similar to m_depth)
- sci_water_temp
- sci_water_cond (something like 4-6)
- sci_flntu_chlor_units (?)
- sci_flntu_turb_units (?)
- sci_oxy3835_wphase_oxygen (>100 at surface)

8.2 Boat

We rented a boat Happy Hooker II (with the Skipper Simon) from a game fishing company based in Mindelo (Bernot; tel. 9915748).

Fig 8: The game fishing boat Happy Hooker II was used for the glider deployments.

8.3 Test & Deployment site

The gliders were tested and deployed south of the Sao Vicente near off the village of Sao Pedro in about 700 m water depth. The deployment location was around 16°46' N / 26°07' E, but varied by a few nautical miles between the different deployments (see Table 2).

8.4 Test procedure

The first dive to 10 m took place with a buoy attached to the gliders. The second dive, again to 10 m was performed with buoy attached. Then, a 100 m dives (shallow gliders) or 150 m dives (deep gliders) were carried out.

8.5 Test and deployment performance

On March 11 three gliders were taken on board of Happy Hooker II, namely IFM 06 (shallow) and IFM 03 and 09 (both deep). All participants (TK, GK, AF, MM, BP, AW) joined the cruise. GK trained AF to run the deployments. IFM 06 performed well in all tests, and was then sent on a mission (200 m max. depth). The gliders IFM09 was recovered after the first test dive (with buoy attached) because it had failed to establish contact the dock server. When we came within sight of the glider, we saw it was right below the surface, and started to descend. We recovered the glider. It was uncertain whether the glider was unable to fill its air bladder (a failure it had in lab tests before – see section 6.3), or whether it was starting a normal descent, after having failed to reach the dock server via Free Wave due to the rough surface conditions. The lesson we learned was to stay closer to the glider throughout the tests.

IFM03 was unable to operate its fin normally, once we release it into the ocean. No cause could be detected. The glider was recovered. On the boat, it then was able to move the fin normally. We currently think that both recovered gliders might actually be deployable in the next days. Both will thoroughly be checked in the lab, and more information on the failure modes will be sought, before attempting to redeploy them.

On March 12 (Friday) IFM07, 10 and 11 were deployed – following the test procedures described above. TK, AF, BP and AW went on the boat. GK stayed in the lab, to take over the steering of the deployed gliders, and MM performed lab tests with the IFM03 and 09. Upon deployment IFM07 turned 'belly-up' at the sea surface, and took a long time to return to the normal position. It was recovered (as the attitude sensor had been deactivated). After rebooting, the attitude sensor showed a permanent roll to one side (right wind up). It was not considered critical as the roll under water during dives was close to zero.

Fig. 9: A glider launched south of Sao Vicente near the village Sao Pedro at about 700m water depth.

On March 13 and 14 (Saturday & Sunday) the sea state was too rough to allow for save deployment operation. On March 15 (Monday) IFM 03 and 09 were deployed aboard Happy Hooker II at the usual site without any major problems by Andreas Funk assisted by Bernd Peters and Albert Werner (GKSS). On March 16 (Tuesday) Andreas and Bernd launched the re-ballasted IFM07 successfully.

Table2 : Last deployment of each glider during the March 2010 campaign.

Glider ID	Date	Time [UTC]	Lat [N]	Lon [E]	Remark
03	15/03/2010	15:00	16°46.32‘	25°05.49‘	2nd launch*
06	11/03/2010	12:36	16°46.79‘	25°06.41‘	1st launch**
07	16/03/2010	12:11	16°46.61‘	25°07.13‘	2nd launch***
09	15/03/2010	12:48	16°46.46‘	25°06.05‘	2nd launch*
10	12/03/2010	12:13	16°46.83‘	25°07.03‘	1st launch
11	12/03/2010	15:17	16°46.42‘	25°08.34‘	1st launch

* Gliders 03 & 09 showed problems during test performed during the first deployment on March 11. The gliders were immediately recovered and underwent lab tests before the re-deployment.

** Emergency recovery on March 16 (see section 7.5).

*** Originally deployed on 12/03/2010 glider 07 showed strong roll angle of about 30° at the sea surface. It was thus very unstable, and we recovered it on 15/03/2010. 1000 g of weight plates were subsequently moved from the ceiling to the base of the glider, to lower to center of mass.

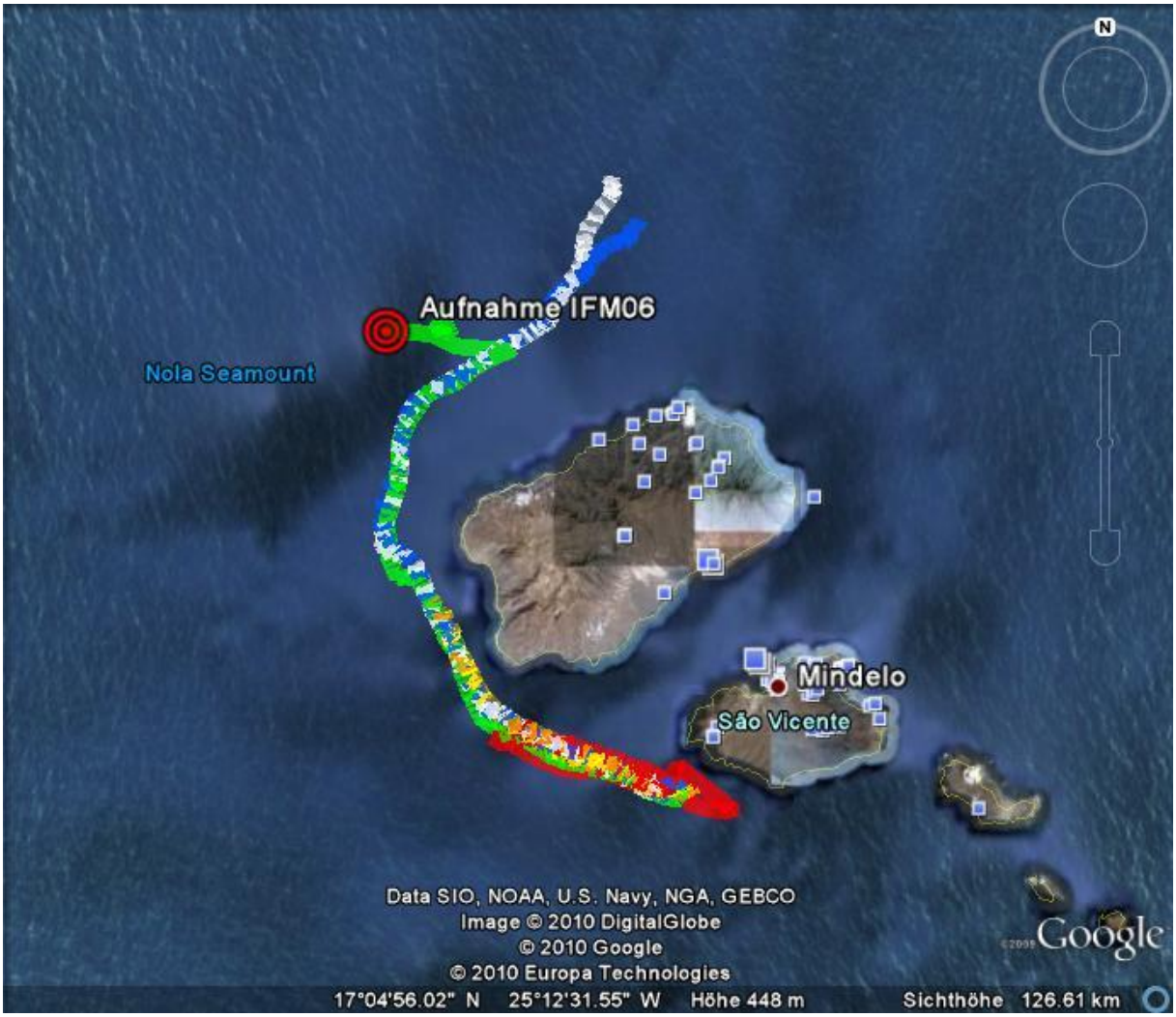

Fig. 10: Tracks of deployed gliders by 17/03/2010.

8.6 Emergency recoveries

On Monday IFM07, which was unstable when residing at the surface, was recovered on Mar 15 10:44 at 16°44.76'N / 25°02.56' E by AF and BP aboard Happy Hooker II.

IFM06 had started to produce several aborts on March 14 (Sunday) cause by leakage detection. This occurred west of Sao Antao, with the glider unable to dive and drifting westward toward Nola Seamount (at about 0.5 nm per hour). We had intended to recover it on March 15, but Skipper Wolfgang did not manage to have his boat ready before 10 am. By the afternoon, no further errors were transmitted and the glider was able to navigate normally. It was steered to the southeast, so that the steam time to recover it should be shorter. The leakage detection errors re-occurred during the night from March 15 to 16. On Tuesday IFM06 was recovered on Mar 16 at 14:42 (UTC) at 17°16.60'N / 25°27.10'W by Mario Müller kindly assisted by Bernd Petersen (GKSS) aboard the game fishing boat *ONDA EMMA* (Skipper Wolfgang).

9. Important phone numbers and addresses

9.1 Skippers

Berno (Skipper of Happy Hooker II). Tel.(00238) 9915748

Berno's wife. Tel. (00238) 9867542

Ferdinand Worst. Tel.: (00238) 9872237

Wolfgang (Skipper of Onda Emma; has radar on board). Tel. (00238) 9875411

Zak (Skipper). Tel. (00238) 9825866

9.2 Hardware Store

Zeferino Rocha CID – Comercio Geral. Tel. / (00238) Fax 313979

Address: Monte Sossego – Rua 1 – 63 A. Sao Vicente

9.3 Other important numbers

Agent of F/S Polarstern: Manuel Lourenco Lima. Agencia Nacional de Viagens. Sao Vicente. PO Box 16 and 142. Tel. (+238) 2321356 or 2321562. Mobile. (+238) 9912606. Home. (+238) 2325556. Email: anvsv@cvtelecom.cv

IFM-GEOMAR Iridium phone +88162145137 (SMS to Iridium phone via http://messaging.iridium.com)

Björn Fiedler's Cape Verdian SIM card. Tel. (00238)

Justino Dios (Water tank lorry) Tel.: +238 9821082

Pericles Silva (INDP). Tel. +238 9549419

TENATSO Phone (back lab): 0238 2326869

10. References

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