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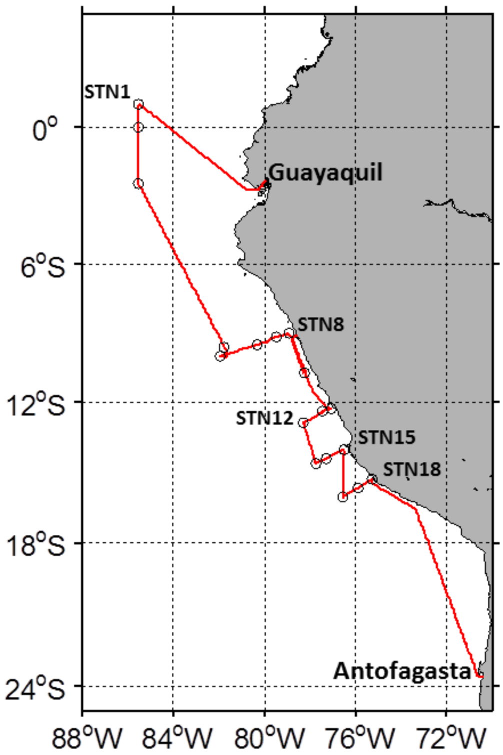
Short Cruise Report
RV SONNE – SO243 ASTRA-OMZ
Guayaquil – Antofagasta
05.10.2015 – 22.10.2015
Chief Scientist: Prof. Dr. Christa Marandino
Captain: Lutz Mallon



Objectives

Dissolved oxygen (DO) concentrations in oceanic regions are declining due to global climate change, resulting in an expansion of oxygen minimum zones (OMZs) and DO decreases in existing OMZs. As a principle determinant of redox state, DO availability plays a key role in regulating biogeochemical processes and nutrient cycles. The availability of redox sensitive trace metals important for various biological production pathways such as those that lead to trace gas production are also impacted by low DO conditions. The ASTRA-OMZ cruise, from Guayaquil to Antofagasta, provided an ideal opportunity to examine 1) the impact of DO in regulating trace gas distributions, and 2) how different biological (e.g. phytoplankton derived surfactants) and physical (e.g. upwelling) variables influence sea-to-air gas exchange. Processes within the shallow OMZ in the eastern tropical south Pacific (ETSP), which is connected to the Peruvian upwelling system and is characterized by high productivity, contribute to enhanced cycling of numerous biogenic trace gases and elevated concentrations of sea-surface surfactants, both of which directly influence atmospheric chemistry and climate. ASTRA-OMZ was a unique platform for multidisciplinary research on OMZs, with chemical, biological, and physical oceanographers working in collaboration with atmospheric scientists. Understanding the role that OMZs play in trace gas formation, as well as the factors that regulate their air-sea exchange, is critical if we are to accurately estimate the supply of trace gases to the atmosphere and predict how this supply may change under future oceanic DO scenarios.

We used conventional methods, such as purge and trap gas chromatography coupled to various sensors, as well as more advanced continuous sampling instrumentation, such as AP-CIMS, to measure a suite of climate active trace gas cycling in the surface ocean. Isotope techniques were used to probe more deeply the sources and sinks of these gases. Surface and atmospheric measurements of trace gas concentrations, along with physical structure (i.e. ozone- and radiosondes) and direct fluxes will be used to quantify emissions and investigate the processes that control their air-sea exchange and atmospheric distribution. State of the art techniques were employed to investigate the role of surfactants on air-sea trace gas exchange. The effects of DO, T and pH on trace metal speciation will be assessed. Additionally we will determine the fluxes of micronutrients (e.g. Fe, Co, Mn) and macronutrients (P, N, Si) to the surface ocean and their consequences for ocean productivity and trace gas production/consumption.

The following parameters were measured during SO243:

- Trace gases – Nitrogen compounds, methane, carbon compounds, sulfur containing and halogen containing compounds, non-methane hydrocarbons
- Isotope signatures of dissolved nitrogen species.
- Nutrient and oxygen concentrations
- Trace metals – Mn, Co, Ni, Cu, Zn, Cd, Pb; the speciation of Mn, Cu; iodide/iodate; Fe(II); Markers for lithogenic origin; ROS-, H_2O_2, superoxide, DOM
- Gas exchange between atmosphere and ocean – Eddy covariance fluxes, atmospheric structure, surface films (microlayer)
- Physical measurements – Tracer release, diapycnal and advective fluxes
- Biological measurements - Biooptical parameters, flow cytometry, identification of phytoplankton, phytoplankton group specific nutrient stoichiometry and rates of production

The subsequent impact of trace gases on atmospheric chemistry (e.g. oxidative processes, ozone formation/destruction) and climate (aerosol and cloud formation) will be determined. We expect that OMZs and the ESTP will enhance the production of certain compounds, such as iodocarbons, DMS, and N_2O, and perhaps lead to greater drawdown of CO_2. The combined effects of higher seawater concentrations of both trace gases and surfactants will have a confounding impact on trace gas fluxes.

Narrative

The FS SONNE left the port of Guayaquil in the morning of 05. October 2015. Around 15:00 local time we left coastal waters and the water pump for underway sampling of surface waters was started. While the ship was heading northwest to our first set of stations, the underway measurements for continuous monitoring of the surface water for N_2O, CO_2, O_2, OCS, total dissolved gases, sea surface temperature, salinity, and chlorophyll were started. Most groups on board began discrete sampling in a 3 hourly rhythm from the underway pumping system. This included samples for nutrients, gases (dissolved O_2, CO_2, N_2O, DMS, halocarbons, isoprene, etc.) and biological parameters. In addition to the water samples, atmospheric samples and radio-/ozonsonde deployments took place with similar timing. During the transit to the first station the eddy covariance (direct flux) measurements of DMS, N_2O and CO_2 were started at the front of the ship.

On the evening of the 06th October we reached the first station in open ocean waters at 1° N, 85.5°W. This was the beginning of a three station repeat ADCP transit. Here we completed two CTD casts (a shallow one of about 100 m and a deeper one of 1000 m), lowered the RAMSES (a light measurement device), and performed microstructure measurements (small scale turbulence in the upper 200 m of the water column). This was a test station; we had to serve the water needs of many gas and biological sampling groups and stretch a new Kevlar wire to be used for trace metal water sampling with Go-Flo bottles. The protocols for CTD casts, depths, and sampling order were finalized and three different types of biological and chemical incubation experiments were started.

After a 10 hour transect southwards along 85.5°W we reached the second station. Here we added the Zodiac for microlayer samples and a continuously sampling profile pump for continuous O2 and trace gas depth profiles (to 150 m) to the deployment rotation. Furthermore, the trace metal group started sampling the water column using their Go-Flow bottles at the new Kevlar wire. Moving further south, after another 12 hour transect, we came to station 3, where we performed our normal station work and added the first of three particle pumps tests. They were attached to the CTD wire at three different depths and pumped for about two hours in order to collect particles on the inserted filters for later analysis. Unfortunately, this test was not successful. We finished station 3 in the afternoon of October, 7 and started our transect to the coast.

On our way to the coast we began our hunt for a mode water eddy. Eddies are rotating mesoscale structures in the ocean that contain different water properties than their surroundings. Recently, eddies have been identified as low oxygen natural laboratories, in which we can investigate how the biogeochemistry is different from the surrounding waters. In the morning of the 10th October we arrived at the approximate location of the predicted eddy and did a first CTD cast. Heading to the center of the eddy, we made a CTD cast approximately every 5 nm in order to find the core. The core was located at approximately 10°S, 82°W, but was, unfortunately, a normal anticyclonic eddy. We resumed with our transect to the coast with the extensive station work at three stations off the

Peruvian coast (one on the boundary of the eddy, one in shelf water outside the eddy, and one at the coast). Near the coast we found signs of upwelling (enhanced values for CO_2 and N_2O and decreased temperature). But the upwelling signal was less pronounced than expected, which may have been caused by the strong El Nino conditions we encountered during the cruise.

Our cruise track led us further south along the coast, always staying in upwelled water masses, until station 9 where the first water mass tracer deployment took place. Here the Ocean tracer injection system (OTIS) was deployed. The OTIS is designed to be towed behind the ship at a set density surface. However, this time we wanted a tracer release very close to the bottom, so the OTIS got "legs" and "feet" so that we could deploy the OTI“ on the bottom of the ocean and release the tracer there. The reason for the close-to-bottom release is that we wanted to mimic release of nutrients from anoxic sediments, and qualitatively understand where ocean currents and mixing processes distribute the nutrients (i.e. the tracer) over a longer time-period. Anoxic sediments are known to release nutrients, such as phosphate and reduced iron, both of which have the potential to enhance productivity in the region – and initiate a positive feed-back loop. At this time we were faced with a problem regarding our measurements: the liquid nitrogen generator broke down and we ran out of liquid nitrogen. Given that approximately 1/3 of the cruise participants depended in some way on measurements made with liquid nitrogen, plus others use liquid nitrogen to flash freeze samples, this was a serious concern. It was a hard call, but we decided to risk our schedule and go to port in Chimbote, Peru to buy 140 L of liquid nitrogen. This took approximately 1.75 days to accomplish, which required that we adjust our cruise plan in order to save time but still accomplish our major goals.

The last set of stations, 10-18, were designed to obtain contrasting measurements between strong upwelling and open ocean conditions (on shore/off shore transects). At station 11 and station 15, the OTIS and particle pumps were deployed simultaneously. These last particle pump deployments were successful. At station 12, a NAVIS float containing dissolved oxygen, temperature, and salinity sensors was successfully deployed. The float is currently in communication with researchers at GEOMAR and Villefranche, sending valid data every 10 days. Unfortunately, between stations 12 and 13, the trace metal tow fish was lost, but the trace metal group was able to maintain most of their sampling program. Strong upwelling was detected around station 15, which was slightly further south than anticipated. After station 15, we had to divert our course again due to the presence of a Peruvian nature reserve, but arrived at our revised station 16 with enough time to include high resolution CTD casts in the sampling program for the first time. At our last station, station 18, we performed our longest program, during which time we deployed all instruments and included several high resolution casts. It was between this station and station 17 that we detected the strongest upwelling signal over the entire cruise track.

The FS Sonne arrived at the pilot at 8:00 on 22nd October, after 2 days of underway measurements in Chilean waters. Despite our challenges at sea and our shortened science schedule, we were able to accomplish most of our goals. This is clearly owed to the fantastic team work of the captain and crew on board the FS Sonne, the dedicated and patient work of the 37 ASTRA-OMZ scientists, and even to the much valued help of the two observers.

Acknowledgements

Many thanks to the captain and crew of the R/V Sonne. Their work and help on board was outstanding. We would also like to thank the Control Station of German Research Vessels, Briese Schiffahrt, and the German Federal Foreign Office in Peru for all of their logistical support during SO243. This work was (and continues to be) funded by the BMBF (Project 03G0243A) and the DFG (GR4731/2-1, MA6297/2-1) with additional funding from GEOMAR Helmholtz Centre for Ocean Research Kiel, the Future Ocean Excellence Cluster in Kiel, and the DFG funded Collaborative Research Center 754. The chief scientist contributed with her Helmholtz Young Investigator Group TRASE-EC, funded by the Helmholtz Association through the President's Initiative and Networking Fund.

Participants

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23.	Andreas Pinck	Ing. OTIS/CTD/Engineer OTIS/CTD	GEOMAR
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Institutes

Abbreviation	Institute	City	Country
GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel	Kiel	Germany
AWI	Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung	Bremerhaven	Germany
HZG	Helmholtz-Zentrum Geesthacht Zentrum für Material- und Küstenforschung	Geesthacht	Germany
UIO	University of Oslo	Oslo	Norway
UMASS	University of Massachusetts Dartmouth	Dartmouth	USA
Bigelow	Bigelow Laboratory for Ocean Sciences	East Boothbay	USA

Station list

Leg	Station/ event	Time [UTC]	Latitude [°N]	Longitude [°E]	Gear	Notes
SO243	1-1	2015-10-07 00:39:00.0	-0.9998	-85.5003	CTD	
SO243	1-2	2015-10-07 01:15:00.0	1.0000	-85.5000	Light meter	
SO243	1-3	2015-10-07 02:16:00.0	1.0000	-85.5001	CTD	
SO243	1-4	2015-10-07 04:17:00.0	1.0001	-85.5001	Microstructure | MSS	
SO243	2-1	2015-10-07 14:56:00.0	0.0001	-85.5001	Pump	continous profiling pump
SO243	2-1	2015-10-07 17:49:00.0	0.0001	-85.5001	Pump	
SO243	2-2	2015-10-07 17:56:00.0	-0.0001	-85.5001	Microstructure | MSS	
SO243	2-3	2015-10-07 19:22:00.0	0.0000	-85.5001	CTD	
SO243	2-4	2015-10-07 22:04:00.0	0.0000	-85.5000	Light meter	
SO243	2-5	2015-10-07 22:55:00.0	0.0000	-85.5001	CTD	
SO243	2-6	2015-10-08 01:06:00.0	-0.0001	-85.5001	water sampler | WS [Wasserschoe…]	
SO243	2	2015-10-07 15:06:00.0	0.0000	-85.5001	Rubber boat, Zodiak | ZODIAK	
SO243	3-1	2015-10-08 16:14:00.0	-2.5000	-85.5000	CTD	
SO243	3-1	2015-10-08 16:48:00.0	-2.5000	-85.5000	CTD	
SO243	3-2	2015-10-08 18:09:00.0	-2.5000	-85.4999	Pump	Particle pump
SO243	3	2015-10-08 16:24:00.0	-2.5000	-85.5000	Rubber boat, Zodiak | ZODIAK	
SO243	4-1	2015-10-10 12:40:00.0	-9.5947	-81.7528	CTD	
SO243	4-2	2015-10-10 14:20:00.0	-9.7001	-81.7000	CTD	
SO243	4-3	2015-10-10 15:28:00.0	-9.7746	-81.6537	CTD	
SO243	4-4	2015-10-10 17:24:00.0	-10.0443	-81.6591	CTD	
SO243	5-1	2015-10-10 19:17:00.0	-9.9993	-81.9169	CTD	
SO243	5-1	2015-10-10 19:29:00.0	-9.9995	-81.9167	CTD	
SO243	5-2	2015-10-10 19:52:00.0	-9.9995	-81.9168	Light meter	
SO243	5-3	2015-10-10 20:51:00.0	-9.9995	-81.9167	CTD	
SO243	5-4	2015-10-10 22:08:00.0	-9.9994	-81.9168	Microstructure | MSS	
SO243	5-5	2015-10-10 23:37:00.0	-10.0000	-81.9171	Go-Flo Bottles | GoFlo	
SO243	5-6	2015-10-11 02:27:00.0	-10.0000	-81.9167	Pump	
SO243	5	2015-10-10 19:27:00.0	-9.9993	-81.9169	Rubber boat, Zodiak | ZODIAK	

Leg	Station/ event	Time [UTC	Latitude [°N]	Longitude [°E]	Gear	Notes
SO243	6-1	2015-10-11 13:08:00.0	-9.5134	-80.3076	CTD	
SO243	6-2	2015-10-11 13:41:00.0	-9.5133	-80.3074	Light meter	
SO243	6-3	2015-10-11 14:48:00.0	-9.5132	-80.3074	CTD	
SO243	6-4	2015-10-11 16:00:00.0	-9.5133	-80.3073	Microstructure | MSS	
SO243	6-5	2015-10-11 17:29:00.0	-9.5128	-80.3076	Go-Flo Bottles | GoFlo	
SO243	7-1	2015-10-12 01:05:00.0	-9.1828	-79.4632	CTD	
SO243	7-2	2015-10-12 01:42:00.0	-9.1835	-79.4639	Light meter	
SO243	7-3	2015-10-12 02:04:00.0	-9.1835	-79.4638	CTD	
SO243	7-4	2015-10-12 03:07:00.0	-9.1835	-79.4638	CTD	
SO243	7-5	2015-10-12 03:41:00.0	-9.1834	-79.4638	Microstructure | MSS	
SO243	7-6	2015-10-12 04:40:00.0	-9.1834	-79.4639	Go-Flo Bottles | GoFlo	
SO243	7-7	2015-10-12 05:27:00.0	-9.1835	-79.4638	Pump	continous profiling pump
SO243	8-1	2015-10-12 10:47:00.0	-9.0000	-78.9000	CTD	
SO243	8-1	2015-10-12 11:01:00.0	-9.0000	-78.9001	CTD	
SO243	8-2	2015-10-12 11:16:00.0	-9.0000	-78.9001	Microstructure | MSS	
SO243	8-3	2015-10-12 12:12:00.0	-9.0000	-78.9000	CTD	
SO243	8-4	2015-10-12 12:52:00.0	-9.0001	-78.9000	Go-Flo Bottles | GoFlo	
SO243	8-5	2015-10-12 13:19:00.0	-9.0000	-78.9000	Light meter	
SO243	8	2015-10-12 10:57:00.0	-9.0000	-78.9000	Rubber boat, Zodiak | ZODIAK	
SO243	9-1	2015-10-12 23:50:00.0	-10.7151	-78.2352	CTD	
SO243	9-2	2015-10-13 00:42:00.0	-10.7153	-78.2349	Ocean Tracer Injection System | OTIS	
SO243	10-1	2015-10-15 15:50:00.0	-12.2537	-77.0773	CTD	
SO243	10-1	2015-10-15 16:05:00.0	-12.2535	-77.0774	CTD	
SO243	10-2	2015-10-15 16:17:00.0	-12.2535	-77.0774	Light meter	
SO243	10-3	2015-10-15 16:48:00.0	-12.2535	-77.0774	Go-Flo Bottles | GoFlo	
SO243	10-4	2015-10-15 17:35:00.0	-12.2535	-77.0774	CTD	
SO243	10-5	2015-10-15 18:05:00.0	-12.2535	-77.0774	Microstructure | MSS	
SO243	10	2015-10-15 16:01:00.0	-12.2537	-77.0773	Rubber boat, Zodiak | ZODIAK	

Leg	Station/ event	Time [UTC	Latitude [°N]	Longitude [°E]	Gear	Notes
SO243	11-1	2015-10-15 20:27:00.0	-12.3640	-77.4375	CTD	
SO243	11-1	2015-10-15 21:02:00.0	-12.3640	-77.4375	CTD	
SO243	11-2	2015-10-15 21:04:00.0	-12.3639	-77.4376	Ocean Tracer Injection System | OTIS	
SO243	11	2015-10-15 20:37:00.0	-12.3640	-77.4375	Rubber boat, Zodiak | ZODIAK	
SO243	11	2015-10-15 21:05:00.0	-12.3639	-77.4376	Pump	Particle Pump
SO243	12-1	2015-10-16 11:40:00.0	-12.8926	-78.2722	CTD	
SO243	12-2	2015-10-16 12:58:00.0	-12.8927	-78.2720	Go-Flo Bottles | GoFlo	
SO243	12-3	2015-10-16 15:05:00.0	-12.8927	-78.2720	CTD	
SO243	12-4	2015-10-16 15:37:00.0	-12.8928	-78.2720	Light meter	
SO243	12-5	2015-10-16 16:16:00.0	-12.8927	-78.2720	Microstructure | MSS	
SO243	12-6	2015-10-16 17:15:00.0	-12.9024	-78.2674	Float	
SO243	13-1	2015-10-17 02:44:00.0	-14.6266	-77.7468	CTD	
SO243	13-1	2015-10-17 05:22:00.0	-14.6497	-77.7341	CTD	
SO243	13-2	2015-10-17 03:14:00.0	-14.6265	-77.7468	Microstructure | MSS	
SO243	13-3	2015-10-17 04:38:00.0	-14.6490	-77.7345	Light meter	
SO243	13-4	2015-10-17 06:34:00.0	-14.6497	-77.7341	Go-Flo Bottles | GoFlo	
SO243	13-5	2015-10-17 08:43:00.0	-14.6496	-77.7340	CTD	
SO243	14-1	2015-10-17 12:00:00.0	-14.4032	-77.2811	CTD	
SO243	14-1	2015-10-17 12:47:00.0	-14.4033	-77.2812	CTD	
SO243	14-2	2015-10-17 13:24:00.0	-14.4033	-77.2811	Light meter	
SO243	14-3	2015-10-17 14:17:00.0	-14.4033	-77.2812	CTD	
SO243	14-4	2015-10-17 14:48:00.0	-14.4033	-77.2812	Go-Flo Bottles | GoFlo	
SO243	14-4	2015-10-17 17:58:00.0	-14.4036	-77.2809	water sampler | WS [Wasserschoe…]	
SO243	14-5	2015-10-17 17:00:00.0	-14.4035	-77.2810	Microstructure | MSS	
SO243	14	2015-10-17 12:10:00.0	-14.4032	-77.2811	Rubber boat, Zodiak | ZODIAK	
SO243	15-1	2015-10-17 22:00:00.0	-14.0360	-76.5278	CTD	
SO243	15-2	2015-10-17 22:31:00.0	-14.0361	-76.5278	Light meter	
SO243	15-3	2015-10-17 23:03:00.0	-14.0360	-76.5277	CTD	

Leg	**Station/ event**	**Time [UTC**	**Latitude [°N]**	**Longitude [°E]**	**Gear**	**Notes**
SO243	15-4	2015-10-17 23:38:00.0	-14.0361	-76.5278	Go-Flo Bottles | GoFlo	
SO243	15-5	2015-10-18 00:38:00.0	-14.0361	-76.5278	Ocean Tracer Injection System | OTIS	
SO243	15	2015-10-17 21:10:00.0	-14.0360	-76.5278	Rubber boat, Zodiak | ZODIAK	
SO243	15	2015-10-18 00:39:00.0	-14.0361	-76.5278	Pump	Particle Pump
SO243	16-1	2015-10-18 19:03:00.0	-16.0748	-76.5789	CTD	
SO243	16-1	2015-10-18 19:15:00.0	-16.0750	-76.5790	CTD	
SO243	16-2	2015-10-18 19:34:00.0	-16.0750	-76.5790	Light meter	
SO243	16-3	2015-10-18 20:17:00.0	-16.0751	-76.5790	CTD	
SO243	16-4	2015-10-18 21:32:00.0	-16.0751	-76.5789	Go-Flo Bottles | GoFlo	
SO243	16-5	2015-10-18 23:57:00.0	-16.0751	-76.5790	CTD	
SO243	16-6	2015-10-19 01:36:00.0	-16.0751	-76.5788	Microstructure | MSS	
SO243	16	2015-10-18 19:13:00.0	-16.0748	-76.5789	Rubber boat, Zodiak | ZODIAK	
SO243	17-1	2015-10-19 06:52:00.0	-15.6737	-75.8951	CTD	
SO243	17-2	2015-10-19 08:05:00.0	-15.6737	-75.8951	Light meter	
SO243	17-3	2015-10-19 08:57:00.0	-15.6737	-75.8950	CTD	
SO243	17-4	2015-10-19 09:34:00.0	-15.6737	-75.8950	Go-Flo Bottles | GoFlo	
SO243	17-5	2015-10-19 12:04:00.0	-15.6681	-75.8987	Microstructure | MSS	
SO243	17-5	2015-10-19 12:51:00.0	-15.6769	-75.8932	Microstructure | MSS	
SO243	17	2015-10-19 12:14:00.0	-15.6681	-75.8987	Rubber boat, Zodiak | ZODIAK	
SO243	18-1	2015-10-19 17:43:00.0	-15.3186	-75.2746	CTD	
SO243	18-1	2015-10-19 18:08:00.0	-15.3184	-75.2745	CTD	
SO243	18-2	2015-10-19 18:11:00.0	-15.3184	-75.2744	Light meter	
SO243	18-3	2015-10-19 18:52:00.0	-15.3184	-75.2745	CTD	
SO243	18-4	2015-10-19 19:26:00.0	-15.3185	-75.2745	Pump	continous profile pump
SO243	18-5	2015-10-19 21:54:00.0	-15.3185	-75.2745	CTD	
SO243	18-6	2015-10-19 23:20:00.0	-15.3185	-75.2745	Go-Flo Bottles | GoFlo	
SO243	18-7	2015-10-20 00:34:00.0	-15.3184	-75.2745	CTD	
SO243	18-8	2015-10-20 01:11:00.0	-15.3184	-75.2745	Microstructure | MSS	
SO243	18	2015-10-19 17:53:00.0	-15.3186	-75.2746	Rubber boat, Zodiak | ZODIAK	