SO287

Pan-Atlantic connectivity of marine biogeochemical and ecological processes and the impact of anthropogenic pressures

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SO287-CONNECT FROM LAS PALMAS TO GUAYAQUIL IN WINTER 2021/2022

The transit of R/V SONNE from Las Palmas (11.12.2021) to Guayaquil, Ecuador (11.01.2022) was directly related to the international collaborative project SO287-CONNECT of GEOMAR in cooperation with Hereon and the University of Bremen, supported by the German Federal Ministry of Education and Research (BMBF) between October 2021 and January 2024. The research expedition was conducted to decipher the coupling of biogeochemical and ecological processes and their influence on atmospheric chemistry. A comprehensive work program combined continuous underway water and atmospheric sampling and measurements, incubations, as well as 36 stations from the upwelling zones off Africa into the Sargasso Sea and further to the Caribbean and the equatorial Pacific.

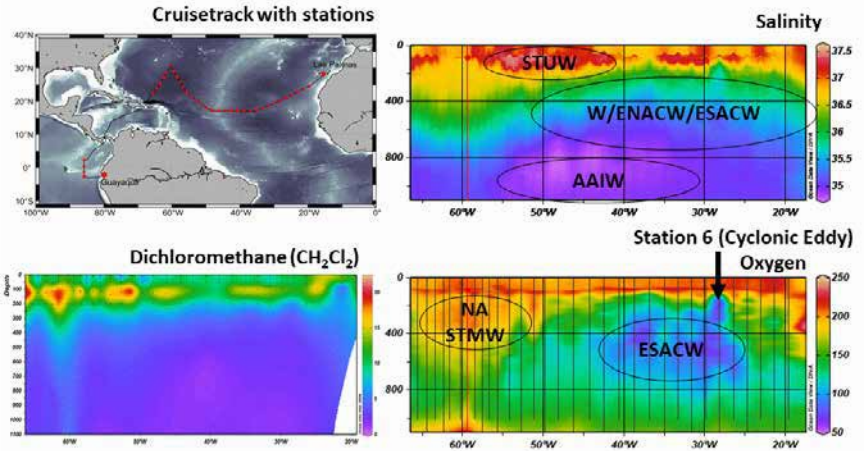

Figure 1: Track chart of R/V SONNE cruise SO287-CONNECT with stations (upper left). Salinity (upper right) and oxygen (lower right), with encountered water masses along the route in the top 1100 m of the Atlantic as North Atlantic Subtropical Mode water (NASTMW), subtropical Underwater (SUW), western and eastern North and South Atlantic Central Waters (W/ENACW/ESACW), Antarctic intermediate water (AAIW), dichloromethane (pM) in the upper water column (lower left).

WATER MASS ANALYSIS ALONG THE NORTH EQUATORIAL CURRENT

With the Extended Multi-parameter analysis (OMP) from Karstensen & Tomczak (1998) with source water types (SWT) based on Liu & Tanhua (2021), eight upper and lower

central water masses, Antarctic Intermediate and Mediterranean Water, as well as North Atlantic Deep Waters, Antarctic Bottom and Northeast Atlantic Bottom Water were analysed in the Atlantic transect. Based on a literature search, it was possible to additionally identify North Atlantic Subtropical Mode water and subtropical Underwater (Goes et al., 2005) in the upper depth ranges. An interesting feature in the OMP analysis is related to the higher proportions of SACW at station 6, which is related to a cyclonic low-oxygen eddy (Figure 1). The water masses sampled at this station were significantly different from the other stations, which underlines the efficiency of eddies formed in the Mauritanian upwelling region in transporting tracers from the coast to the open ocean.

The biogeochemical and ecological processes along the cruise track need to be interpreted on the background of this water mass analysis, e. g. for marine and atmospheric halocarbons during the cruise.

HALOCARBON DYNAMICS

The spatial variations of natural and anthropogenic short-lived bromo-, chloro- and iodocarbons, e. g. bromoform ($CHBr_3$), methyl iodide (CH_3I), di- and trichloromethane (CH_2Cl_2 $CHCl_3$) were highly dynamic in both the ocean and atmosphere. Production of brominated and, surprisingly, chlorinated methanes occurred in the deep chlorophyll maximum (Figure 1), while the chemistry of iodinated compounds was closely related to light. The cycling of anthropogenic chlorinated compounds was coupled to water mass formation and transport. First time incubation experiments of halocarbon release from the floating seaweed species *Sargassum* spp. suggest, that during its extensive blooms in the Atlantic, this brown seaweed plays an important role in the emissions of natural halogens and organic matter.

MARINE CARBON AND NITROGEN CYCLING

Marine carbon cycling was tightly coupled to differences in microbial diversity, activity, and abundance from the Canary current upwelling system into the subtropical gyre. Phosphorus availability was an important driver of shifts in the bacterial community composition along the transect affecting the semi-labile DOM pool, supported by pronounced changes in the relative proportion of transcribed genes associated with the utilization of phosphorus and transcription of carbohydrate-active enzymes.

The vertical distribution of gel particles was investigated along the cruise track from the surface to the deep sea. Significant distinctions were found in terms of particle abundances and sizes between the productive upwelling system at the northwest coast of Africa compared to the open ocean regime in the western north Atlantic.

Ambient atmospheric concentrations of nitrogen dioxide (NO_2, manmade pollutant) were highly variable, but were typically below 0.1 parts per billion (ppbv) in air from "clean sector" wind directions unperturbed by the ship's own emissions. Even at night, no molecular iodine (I2, natural emissions) above the instrument's detection limit (~1 pptv)

was observed, except for a small iodine signal (~2 pptv) in the equatorial Pacific. Time series measurements of the solar flux, photosynthetically active radiation (PAR), and the photolysis rate coefficients for 16 photolabile atmospheric gases will be used for the interpretation of halocarbon cycling above the subtropical North Atlantic.

As the cruise went through the Equatorial Tropical Pacific (ETP), we took the opportunity to revisit a section at 85.5°W, which covers the ETP oxygen minimum zone (OMZ) that has been sampled and investigated on prior cruises. All ocean surface waters were above or close to equilibrium with respect to the corresponding atmospheric values of nitrous oxide (N_2O) and methane (CH_4). Enhanced N_2O saturations were observed in the vicinity of the Canary current upwelling system and above the OMZ in the ETP. Enhanced CH_4 saturations were also observed in coastal waters of the ETP. N_2O concentrations within the hypoxic zone were twice as high as those in the rest of the water column during SO287. Comparison of depth-integrated concentrations of dissolved N_2O with previous cruises reveals comparatively high values during La Niña years, maximizing during SO287.

SO287 connect was the first study to measure surface dissolved nitric oxide (NO) concentration across the Atlantic Ocean. Dissolved NO concentrations ranged from 9.38 to 48.24 pM (average: 13.89 ± 5.82 pM). Notably higher concentrations were observed in the eastern Tropical North Atlantic Ocean, southeast of the Azores Archipelago, and northwest of the Canary Islands. The sea-to-air-flux ranged from 1.12×10^{-18} to 4.78×10^{-17} mol m^{-2} s^{-1} (average: $1.50 \pm 0.99 \times 10^{-17}$ mol m^{-2} s^{-1}), indicating that the open ocean was a notable source of NO to the atmosphere during this campaign.

A metagenomic approach was utilized across a dissolved oxygen (DO) gradient from oxic to suboxic conditions in the ETP. The findings were compared to the Tara Ocean datasets obtained from the same region under a comparable La Niña event in 2011. SO287 observed a decrease in microbial diversity and abundance, coupled with an increase in most nitrogen metabolisms as DO decreased. Dominant microbial groups and key functions displayed varying sensitivities to different DO ranges (5 to >120 µmol/kg). The shift in functional groups occurred when DO dropped below 120, 90, 80, 60, or 12 µmol/kg. A significant reduction in the relative abundance of SAR11, along with an increase in nitrogen metabolisms, e. g., denitrification (N_2O production) and nitrogen fixation, were observed in our datasets comparing to Tara Ocean datasets. The study improves our understanding of the response of microbial diversity, groups, and functions to a future OMZ expansion and how ENSO events impact in-situ microbial community and their roles.

INFLUENCE OF SHIP EMISSIONS ON DMS

Dimethyl sulfide (DMS) biogenically produced in the ocean is an important precursor of cloud condensation nuclei in the remote marine boundary layer and therefore influences the radiation budget of the Earth. The goal during SO287 was to investigate, how ship

emissions (i. e. use of scrubbers) impact the trace gas biogeochemistry in the surface ocean. Incubation experiments revealed a significant difference of DMS concentrations between the scrubber treatment and the controls. DMS concentrations in the scrubber treated water are drastically reduced at the start of the experiment indicating an immediate effect (possibly pH related) of scrubber water addition on the actual DMS concentration. Initial DMSO concentrations in the scrubber treated water were significantly higher than in the control during the experiment with a 2% scrubber addition indicating a pH induced oxidation to DMSO. The overall decrease of the climate relevant trace gas DMS through addition of scrubber effluent could facilitate climate change.

TRANS-ATLANTIC MICRO-PLASTIC

95% of plastic particles along the transect were either polyethylene (PE) or polypropylene, with PE clearly dominating. Furthermore, the distribution of the plastic particles along the transect was defined by a few stations with high concentrations, such as the one in the North Atlantic garbage patch located in the North Atlantic gyre.

UPTAKE OF OZONE TO THE OCEAN

Atmospheric ozone levels and uptake of ozone to the ocean alongside biogeochemical properties of the seawater (including iodine speciation, fatty acid composition, DOC concentrations and surface tension) were measured in order to investigate the mechanisms of ozone uptake. Measured ambient ozone mixing ratios 10 m above sea level were between ~ 5 – 40 ppb. The highest concentrations were observed in the Atlantic (35.0 ± 2.6 ppb), followed by the Caribbean (17.7±2.1 ppb) and ETP (6.5 ± 1.4 ppb). Ozone uptake to seawater was measured for samples from the CTD, underway system and from the sea-surface microlayer (SML). The SML was the most reactive towards ozone, with chemical reactivity to ozone on average 17% higher than in the underlying water. Iodine speciation (iodide, iodate, dissolved organic iodine, total inorganic iodine and total dissolved iodine) was measured for all samples, with the reduced form, iodide, representing the most ozone-reactive fraction. Mean (±sd) iodide concentrations in the CTD, SML and underway samples were 140±24, 59±11 and 139±29 nM, respectively, revealing a significant depletion of iodide in the SML compared to the near-surface CTD sample. Mean total dissolved iodine concentrations were 438±20, 401±15 and 397±15 nM for CTD, SML and underway samples. The SML samples were enriched in DOC relative to the CTD samples (EF=1.4) and their concentration range was far greater (0.68–8.9 mgL^{-1} vs 1.4–2.6 mgL^{-1}). SML surface tensions were depressed relative to the CTD seawater (72.1±1.6 vs 73.5±0.2) indicating enhanced surfactant concentrations in the SML. The DOC and surface tension measurements show that there is increased organic material concentration within the SML. This dataset will help improve our understanding of the mechanism and rates of ozone uptake to the ocean.

PLANKTON DIEL MIGRATION

Sea temperature and dissolved oxygen were identified as primary drivers of SSLs distribution, highlighting their significance in oceanic ecosystems and global climate

regulation. The planktonic sound scattering layer (SSLs) revealed strong regional variations in the Atlantic and Pacific and responses to environmental factors in the North Atlantic Gyre. Sea temperature and DO were identified as primary drivers of SSL distribution, highlighting their significance in oceanic ecosystems and global climate regulation. The Pacific's shallow SSLs were linked to the OMZ.

REFERENCES

Karstensen J, Tomczak M, Age determination of mixed water masses using CFC and oxygen data. Journal of Geophysical Research: Oceans 1998, 103(C9), 18599–18609. https://doi.org/10.1029/98JC00889.

Liu M, Tanhua T, Water masses in the Atlantic Ocean: Characteristics and distributions. Ocean Science 2021, 17(2), 463–486. https://doi.org/10.5194/os-17-463-2021.

Goes M, Molinari R, da Silveira I, Wainer I, Retroflections of the north brazil current during February 2002, Deep-Sea Res. Pt. I 2005, 52, 647–667, https://doi.org/10.1016/j.dsr.2004.10.010.

SCIENTIFIC OUTPUT

LIST OF PUBLICATIONS

Auganæs, S, Ozone above the tropical Atlantic ocean, 19. June 2023 at the University of Oslo.

Bi S, Hieronymi M, Röttgers R, Bio-geo-optical modelling of natural waters, Front. Mar. Sci. 2023, 10, 1196352. doi: 10.3389/fmars.2023.1196352.

Böhme W, On the relationships between dissolved organic matter, inorganic nutrients, and the bacterial community composition in the tropical North Atlantic Ocean", Masterthesis, 06. April 2023 at the Christian-Albrechts-Universität zu Kiel (CAU Kiel).

Karnatz J, Sargassum seaweed in the North Atlantic and its potential contributions to the emissions of halocarbons and DOC", Masterthesis 02. December 2022 at the Christian-Albrechts-Universität zu Kiel (CAU Kiel).

Keß K, Interaction of dimethyl sulphide (DMS) and hypobromous acid (HOBr) in global ocean surface waters, Masterthesis 20. August 2023 at the Christian-Albrechts-Universität zu Kiel (CAU Kiel).

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