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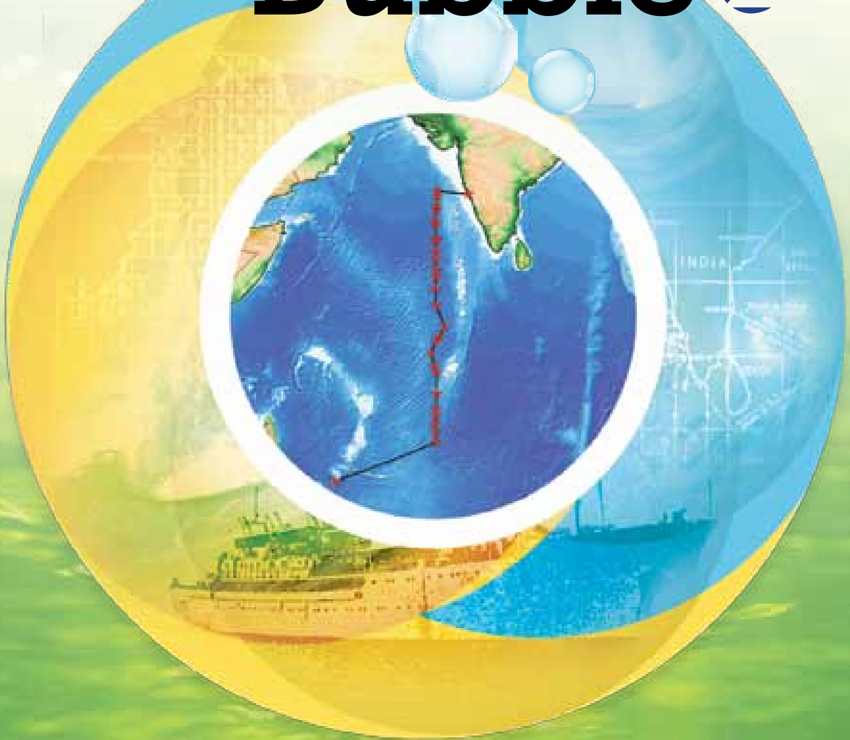
INTERNATIONAL INDIAN OCEAN EXPEDITION

The Indian Ocean Bubble 2



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OASIS-research cruises SO234-2 and SO235 of R/V SONNE in summer 2014 in the tropical Indian Ocean investigating "Organic very short lived substances and their Air-Sea exchange from the Indian Ocean to the Stratosphere" and more biogeochemical and oceanographic parameters

Fig. 1: Chief Scientist Prof. Dr. Kirstin Krüger with Co-PI's Prof. Dr. Christa Marandino and Dr. Birgit Quack (from right to left).

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Within the frame work of the project OASIS ("Organic very short lived substances and their Air Sea Exchange from the Indian Ocean to the Stratosphere") the research cruises SO234-2 (Durban- Port Louis, 08-20 July, 2014) and SO235 (Port Louis – Male, July 23 to August 07, 2014) of the German research vessel SONNE were organized and conducted by the University of Oslo, Norway (www.uio.no) together with the GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany (www.geomar.de) in the subtropical and tropical West Indian Ocean (Fig. 1). The SO234-2 cruise was primarily planned as a training and capacity building cruise for students from southern Africa and Germany within the BMBF SPACES ("Science Partnerships for the Assessment of Complex Earth System Processes") programme. Fifteen students from South Africa, Namibia and Germany participated, along with 9 scientists and one observer from Madagascar. The SO235 cruise was planned as a pilot study for upcoming research in IIOE-2 to the tropical West Indian Ocean. Twenty-three scientists from Germany, Austria, China, Italy, Malaysia, UK and USA and one observer from Mauritius took part. The training and research covered air-sea gas exchange between the atmosphere and the ocean, and the transport of ocean trace gases from the Indian Ocean to the stratosphere during the southwest Monsoon as well as the determination of important biogeochemical and oceanographic parameters. The cruises were funded from the German Federal Ministry for Education and Research (BMBF) within the project SO235-OASIS (BMBF grant: 03G0235A).

Scientific background:

Trace gases, containing halogens like chlorine and bromine are broken down by solar radiation in the stratosphere, where the halogens are highly efficient at destroying ozone. Increasing emissions from human activities have led to depletion of global stratospheric ozone over the last three decades. Whereas the chlorine supply is dominated by anthropogenic compounds, a major part of the bromine is supplied by natural, short-lived compounds with oceanic sources. The importance of sulphur compounds emitted from the ocean for the middle atmosphere relates to their role as precursors for the stratospheric aerosol layer. Recently, an increase of the stratospheric aerosol background level since 2000 has been observed. However, the origin of this elevated Junge layer, either anthropogenically or naturally, is still under investigation. The tropical oceans are a known source of reactive halogen and sulphur compounds to the atmosphere in the form of short-lived brominated and iodinated methanes, such as bromoform ($CHBr_3$) and methyl iodide (CH_3I), dimethyl sulphide (DMS) and COS (carbonyl sulphide). Elevated atmospheric concentrations above the oceans are related to oceanic super saturations of the compounds, and to natural photochemical and biological production. Macro algae in coastal regions, as well as regionally enhanced phytoplankton, coral reefs, photochemical reactions and local anthropogenic sources all contribute to marine and atmospheric concentrations.

Trace gases enter the stratosphere principally in the tropics, where deep convection carries them rapidly from the ocean surface to the tropical tropopause layer. The intense vertical transport of the tropical atmosphere implies that the oceanic sources supply significant amounts of halogens and sulphur to the upper troposphere/ lower stratosphere where they contribute to the observed halogen and sulfur loadings and ozone changes. The subtropical and tropical Indian Ocean is a largely uncharacterized region for oceanic compounds and a projected hot spot, especially in coastal regions for their emissions and transport pathways into the stratosphere during southwest monsoon.

Spatial and temporal variability in production and sea-to-air flux of short-lived halogenated and sulphuric trace gases creates strongly varying oceanic distributions and thus also varying atmospheric contributions. The current impact of the natural ozone depleting substances is still uncertain and future changes in the mechanisms, that regulate their emissions to the atmosphere, their emissions to the atmosphere, their transport, and their chemical processing are largely unknown. Therefore the oceanic emissions have the potential to cause surprises in the future evolution of the stratospheric ozone with respect to a decreasing chlorine background and aerosol layer in a changing climate, unless they are better understood. The Asian monsoon circulation provides an effective pathway for air masses from the atmospheric boundary layer to enter the global stratosphere during boreal summer. The role of biogenic emissions from the tropical Indian Ocean and their entrainment into the stratosphere has not been investigated yet. In order to better understand chemical and dynamical processes controlling ozone concentrations from the surface to the stratosphere, it is important to investigate the influence of oceanic trace gas transport through the Asian monsoon circulation on atmospheric composition.

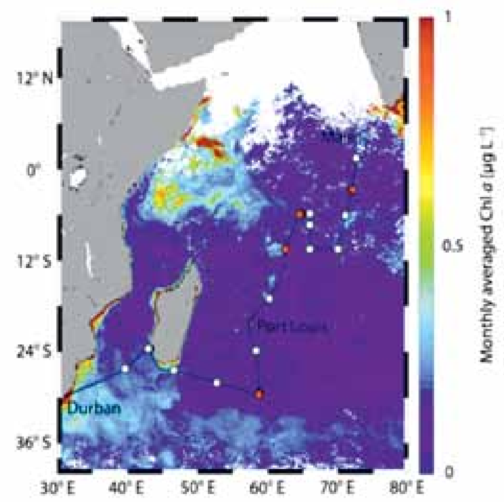

Fig. 2 Cruise track of SO234-2 (Durban- Port Louis, 08 -20 July, 2014) and SO235 (Port Louis – Male, July 23 to August 07, 2014). Dots mark oceanic depth profile -stations, while red dots mark 24 hour stations.

The tropical Indian Ocean measurements are thus important to improve the understanding of future stratospheric halogen and sulphur loading and therewith on the ozone depletion and the radiative forcing of the future climate. The results of the SO234-2 and SO235 ship campaigns will contribute to new scientific insights of the United Nations Montreal Protocol on Substances that Deplete the Ozone Layer, to the United Nations Framework Convention on Climate Change and to global climate change research in general.

The cruises:

The cruises SO234-2 and SO235 (Fig. 2) were planned as training and pilot study to characterize the oceanic sources and emissions of natural halogenated and sulphuric gases in the subtropical and tropical West Indian Ocean and their delivery to the stratosphere during Southwest Monsoon. The western Indian Ocean experiences the Somali current, which reverses with the different monsoon systems, the Agulhas current, open ocean denitrification and high rates of nitrogen fixation in the Arabian Sea and a large area in the western equatorial region of high carbon dioxide drawdown. All these phenomena make the Indian Ocean an excellent laboratory for ocean biogeochemical and physical processes, atmosphere-ocean interactions and for global climate change studies with a special focus on anthropogenic versus natural effects.

Of particular scientific relevance during the cruises were oceanic and atmospheric measurements of a suite of short-lived trace gases containing bromine, iodine and sulphur in various marine biogeochemical regimes like close to the coasts, in regions of high chlorophyll, close to coral reefs (as the Cargados Carajos Shoals and Maldives) and sea banks (i.e. Saya de Malha bank) and open ocean conditions. From these measurements the climate-sensitive oceanic emission strengths and their contribution to stratospheric halogen and sulphur aerosol abundances will be deduced by high resolution transport modelling.

Work programme during the cruises:

During the cruises of RV Sonne from July 08 to August 07, 2014 in the subtropical/ tropical West Indian Ocean a variety of chemical, biological and physical parameters within the surface waters as well as between the atmospheric boundary layer and the stratosphere have been examined with different frequencies. Data and samples were obtained using various analytical instruments and sampling devices. Three-hourly surface water samples were collected from pumps submersed in the hydrographic shaft of the ship, while discrete air samples were taken with metal bellows pumps on the monkey deck. Oceanic depth profiles were undertaken at selected locations (Fig. 2) to investigate the vertical hydrographic structure of the water column and to obtain trace gas profiles. Additionally, a Lagrangian drifter following the water masses at the surface was employed. Several trace gases from sea water and surface air as well as biological parameters were analysed directly on board the ship. In total 48 instruments and sampling devices were employed to analyse the samples during the cruise.

Halogenated hydrocarbons, oxygenated trace gases and dimethyl sulphide (DMS) from sea water and surface air were analysed directly on board using six different gas chromatography and mass spectrometry systems. Carbon dioxide and oxygen were measured immediately with sensors within the upper oceanic layer. More trace gases in sea water (N_2O, CH_4) where analysed by gas chromatography post-cruise in the laboratory. Oxygen was measured on board directly by the Winkler method and optodes and nutrient samples were analysed with micro-molar and nano-molar auto analysers. Biological sampling included parameters of organic carbon and nitrogen as well as DNA, pigments, cell sizes, the amount of small cells and the composition and activity of the phytoplankton and zooplankton.

Atmospheric profiles of temperature, humidity and different kinds of trace gases (e.g. ozone, nitrous oxide, iodine and bromine oxides) were examined on the basis of optical measurements and by rises of research balloons to the stratosphere (up to 30 km height). Optical sensors and continuous instruments were installed in the beginning of the cruise on the monkey deck, the bow and in a research container and discrete air samples were taken. In the respective home laboratories more than 70 anthropogenic and natural trace gases and elements in aerosols within the marine boundary layer were analysed following the cruise.

Frozen water and filter samples of chemical and biology parameters, taken during the cruise, were sent by air freight and were analysed in the respective home laboratories, while the containers with equipment reached Kiel by beginning of October 2014. The analysis of the extensive dataset from the ocean and the atmosphere collected during SO235 will bring first results in summer 2015. The new insights into the interaction of ocean and atmosphere from the tropical West Indian Ocean will be published in peer reviewed scientific journals. The data are currently collected at GEOMAR and will later be available from the World Data Center PANGAEA (http://www.pangaea.de/).

For further information email, and cruise reports are available at http://www.geomar.de/

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