

## SPACES – SCIENCE PARTNERSHIPS FOR THE ASSESSMENT OF COMPLEX EARTH SYSTEM PROCESSES

Research on interactions between geosphere, atmosphere and ocean, as well as the interactions between land and sea and biosphere and atmosphere, are the focus of the systemic research programme SPACES



# CONTENT

<b>INTRODUCTION .....</b>	<b>4</b>
<b>MARINE AND COASTAL RESEARCH .....</b>	<b>6</b>
AGULHAS – Regional and global relevance.....	6
GENUS – Geochemistry and ecology of the Namibian upwelling system.....	9
SACUS – Southwest African coastal upwelling system and Benguela Niños.....	14
<b>LAND-OCEAN INTERACTIONS .....</b>	<b>18</b>
GSI – Groundwater/seawater interaction along the South African south coast.....	18
RAiN – Regional Archives for Integrated iNvestigations .....	21
<b>CHANGING LANDSCAPES .....</b>	<b>24</b>
Limpopo Living Landscapes (LLL) – Dynamics of Ecological and Cultural Landscapes .....	24
ARS AfricaE – Adaptive resilience of Southern African ecosystems .....	27
IDESSA – Decision support system for rangeland management .....	30
OPTIMASS – Sustainable management of savannah ecosystems .....	33
GEOARCHIVES – Signals of climate and landscape changes .....	36
<b>SPACES CAPACITY BUILDING .....</b>	<b>40</b>
<b>ABBREVIATIONS .....</b>	<b>42</b>
<b>APPENDIX .....</b>	<b>43</b>
<b>PROGRAMME MANAGEMENT.....</b>	<b>48</b>
<b>PARTNERS IN SPACES PROGRAMME .....</b>	<b>49</b>
<b>IMPRESSUM .....</b>	<b>50</b>

# INTRODUCTION

For over thirty years the Federal Ministry of Education and Research (BMBF) and a variety of African partner countries have cooperated closely with each other. In 1994 an intergovernmental agreement on bilateral cooperation in science and technology was signed with South Africa. As a result of this, joint research projects such as the Integrated Water Resources Management (IWRM) programme and industry-related projects were established and these have been at the centre of the collaboration for years. Since 2000, positive political developments and a reinforced interest in cooperation in the field of science and research, particularly

from the African partners, have led to an intensive research-oriented partnership between countries. In various jointly published research initiatives, Germany and its partners have risen to one of the biggest challenges of the 21st century: climate change. Together with a number of other impacts of global change, such as the competition for resources, food security and related land use conflicts, Africa is facing ever greater challenges.

Africa is seen as the continent most at risk from global climate change. The decisions of international communities – Bali Action Plan of UNFCCC (2007), Sustainable



Development Summit Rio 20+ and G8 – require support for emerging and developing countries in order to help them adapt to inevitable climate change as a matter of urgency. Numerous African countries and the African Union have also identified areas for action. There is an awareness of the serious consequences of climate change in Africa, but the expertise and empirical data basis for climate protection are patchy.

Soil erosion, drought, the interaction of climatic and anthropogenic influences such as land use, industrial pollution and aquaculture, and the changes in ocean currents are important issues which are currently being examined in the context of climate change. Research on interactions between geosphere, atmosphere and ocean, as well as the interactions between land and sea and biosphere and atmosphere, are the focus of the systemic research programme SPACES (Science Partnerships for the Assessment of Complex Earth System Processes). The SPACES programme aims to implement scientific cooperation projects in the Southern African region that contribute to the formulation of science-based recommendations to policy-makers for Earth system management and ensure the sustainable use and preservation of various ecosystem services in the region. To implement the programme, scientists from German universities and non-university research institutions cooperate with relevant partner institutions in the Southern African focus countries of Namibia and South Africa.

This brochure presents a total of 10 successful projects in Africa and the capacity building programme that are funded by the BMBF as part of the SPACES funding initiative. Three project management agencies administer the SPACES programme: DLR-PT, (DLR Project Management Agency – part of the German Aerospace Center), PTJ (Project Management Jülich – Forschungszentrum Jülich) and PTKA (Project Management Karlsruhe).

The projects illustrate the extremely wide range of challenges that we need to cope with over coming decades and are intended to demonstrate concrete solutions. For example, the key objective of GeoArchives is to develop and interpret geoscientific information sources on the Earth's surface which can then be used to characterise landscape development and climate change in Southern Africa.

The IDESSA project is concerned with understanding the complex interplay of pasture management and savannah dynamics. Against this background, IDESSA aims to implement an integrated monitoring and decision-support system for the management of savannahs in Southern Africa.

The GENUS project, which has already been completed, investigated the causes and effects of climate change on ocean circulation, nutrient cycles, the type and amount of microalgae and on subsequent links in the food chain, including commercially important fish stocks, in the Benguela upwelling area.

# MARINE AND COASTAL RESEARCH

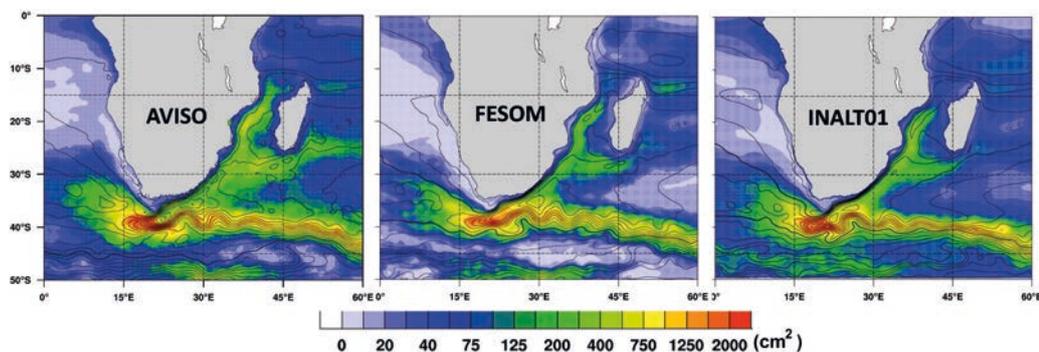
## AGULHAS – REGIONAL AND GLOBAL RELEVANCE

### BACKGROUND

The global overturning circulation shapes the oceanic redistribution of heat and carbon, and influences the global climate. Along its downwelling limbs, anthropogenic trace gases are removed from the atmosphere and stored in the deep ocean on timescales of centuries to millennia. In-depth understanding of the driving mechanisms of the overturning and its temporal evolution are thus fundamental goals of climate science research. Since the original 'conveyor belt' concept, the scheme of the overturning has been redrawn and refined, now revealing less coherent pathways

for both upper and deeper limbs. Despite a more complex picture, key regions still exist where the global overturning converges and where regionally constrained and small-scale processes can have a large-scale impact. The Agulhas region around South Africa is such a key region; here, return flow of surface and intermediate waters from the Indian Ocean leaks into the Atlantic. Agulhas leakage provides heat and salt that is advected towards the subpolar North Atlantic, influencing deep-water formation.

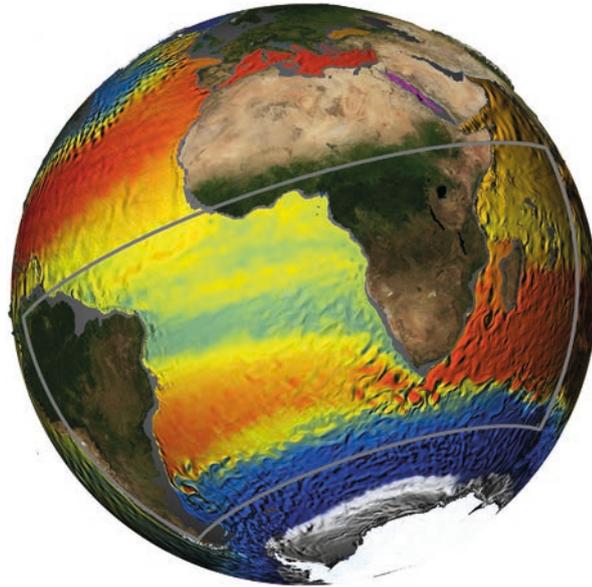
Circulation in the Agulhas region. Shown are variance (colour, in  $\text{cm}^2/\text{s}^2$ ) and mean (contour lines) of the sea surface height in FESOM and INALTO1 compared to satellite data (AVISO).



## OBJECTIVES AND RESEARCH APPROACH

AGULHAS addresses aspects of the regional dynamics in a highly vigorous system and the global relevance of that regional system under a changing climate. The embedment of changes in Agulhas leakage into the large-scale circulation variability calls for numerical studies with global ocean models. Owing to the nonlinear interactions in the Agulhas region, the global modelling strategy must be combined with a sufficient resolution around South Africa. In AGULHAS, two model concepts are compared: a finite-differences model with high-resolution nesting based on NEMO and the finite-element model FESOM. Apart from the individual verification of each model, in particular of FESOM as a next-generation ocean model, the joint evaluation allows model-dependent results to be overcome and robust findings to be obtained. Topics for the analyses include the quantification of Agulhas leakage, its interplay with natural and anthropogenic climate variability, its impact on the global overturning and the exchange with the Southern Ocean.

Regional and coastal dynamics are another important focus of the project. Analyses with the high-resolution models provide a detailed insight into local dynamics. Specific regional topics, such as the interplay of the Agulhas Current with the coastal circulation, are addressed in collaboration and exchange with the South African partners.



Snapshot of 450 m temperature and velocity gradients in the NEMO configuration INALTO1

## STUDY AREA

The Agulhas Current is the main component of the vigorous system around South Africa. After flowing poleward as a boundary current along the east coast of Southern Africa, it abruptly turns eastward and flows back into the Indian Ocean as the Agulhas Return Current. At the retroflection south of Africa, Agulhas rings are shed – a process that is modulated by upstream mesoscale features, resulting in an episodic interoceanic transport and, in consequence, a highly interruptive component of the global overturning. Models suggest that the amount of Agulhas Current waters ending up in the Atlantic Ocean, Agulhas leakage, strongly varies on inter-annual to decadal timescales and has increased over past decades. On multi-decadal time scales Agulhas leakage is linked with the North Atlantic circulation and the global overturning.

## SUBJECT OF RESEARCH

Since the accurate representation of the mesoscale flow and the quantification of Agulhas leakage require sufficient horizontal resolution, AGULHAS concentrates on ocean general circulation models at mesoscale resolution. NEMO is performed in two versions, at  $1/10^\circ$  (INALT01) and  $1/20^\circ$  (INALT20) resolution in the South Atlantic and the western Indian Ocean. The finite element approach in FESOM allows varying of the resolution, in particular in regions of high variability. In the current configuration, the Agulhas Current system is simulated at  $\sim 1/10^\circ$  resolution. All configurations are performed in hindcast mode, in which the atmospheric forcing consists of observationally derived data from the past 60 years. This allows comparisons with ocean observations and the evaluation of the interannual to decadal variability of the circulation.

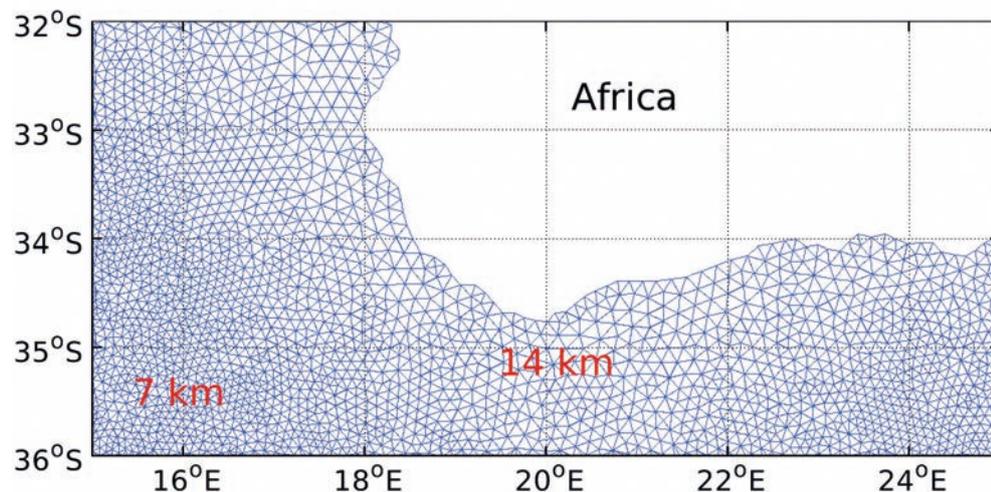
## PROJECT STRUCTURE AND PARTNERS

AGULHAS is organised between two partners: GEOMAR Helmholtz Centre for Ocean Research Kiel runs the established NEMO model with regional nesting refinement, and Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) develops and maintains the finite-element model FESOM. This is the first time this next generation ocean/climate model has been set up and tested in such a dynamically vigorous system. South African partners send students for training purposes and to address specific research questions.



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Mesh with refined resolution around South Africa, calculated in FESOM



RV Maria S. Merian on the coast of Namibia

## GENUS – GEOCHEMISTRY AND ECOLOGY OF THE NAMIBIAN UPWELLING SYSTEM

### BACKGROUND

Climate change is one consequence of human activity that may lead to the reorganization of atmospheric and oceanographic circulation patterns, thus affecting oxygen concentrations and biogeochemical cycles in the ocean, and structures and functioning of marine ecosystems. All these effects of

global climate change have regional ecological and socio-economic implications. For instance, ecosystem regime shifts with dramatic changes in fish stocks have been observed in many eastern boundary upwelling systems, including the Benguela upwelling system off southwest Africa.

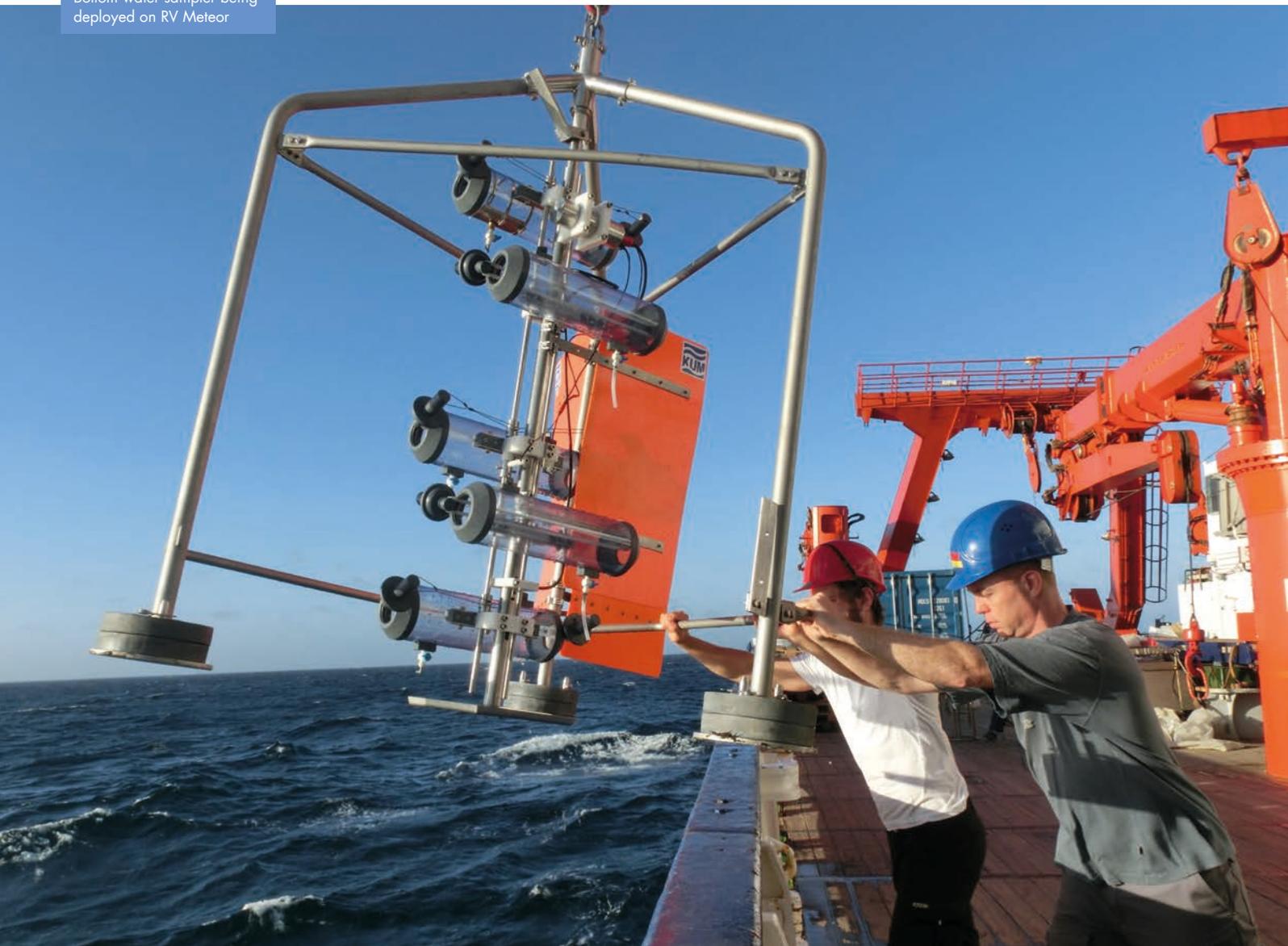
## OBJECTIVES AND RESEARCH APPROACH

Worldwide coastal upwelling systems respond strongly to large-scale natural climate variability and may just begin to react to anthropogenic directed climate change. These systems are ideally suited to discovering the mechanisms by which relatively subtle variations in wind patterns (direction and speed) influence wind-driven ocean circulation patterns, and the interplay of water masses in the zone of upwelling. The effect on watermasses with distinct biogeochemical properties and ecological consequences is also more direct than in other ocean areas. Physical drivers impact the biogeochemistry of the system

(oxygen and nutrient inventories) and, hence, the abundance and composition of microalgae which are the nutritional base for higher trophic levels including important fish stocks.

The GENUS project started in 2009 and involved modellers, biogeochemists and ecologists in developing a comprehensive understanding of upwelling ecosystem dynamics of the northern Benguela system. The central tool for analysis is a model system, tested by and based on extensive field data (derived from ship expeditions) and long-term observations, that simulates the impact

Bottom water sampler being deployed on RV Meteor

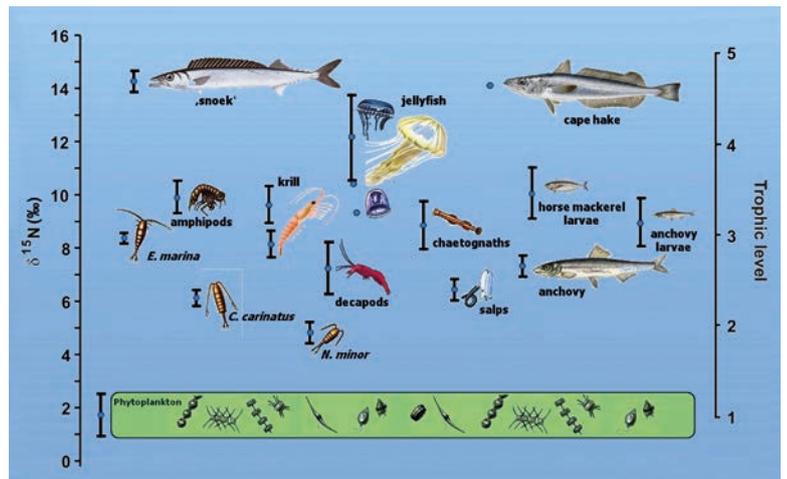


of climate change on the marine environment in the upwelling area off Namibia. The scientists investigated the influence of a shift in wind speed and direction of the Southeast Trade wind system on ocean circulation and water mass properties that mix and upwell over the shelf to the sea surface. They analysed mixing ratios of upwelling source waters to determine both nutrient and oxygen concentrations in the water column over the shelf and the structure of the energy cascade in the food web from phytoplankton to fish. Consequences of these processes for carbon footprints and other radiatively active trace gases were assessed for the upwelling area and the adjacent subtropical South Atlantic Ocean.

The education and training of scientists and technicians from the Benguela region has been a vital component of the cooperative project. Scientists, technicians and students from all three southwest African countries (South Africa, Namibia and Angola) have participated in GENUS ship expeditions on German, Namibian, South African and British research vessels. Incorporated in the scientific efforts of the GENUS project were several master's and PhD theses of scientists from the region which were submitted to universities in Germany, South Africa and Namibia. So far, six PhD students and three master's students from the three southwest African countries have been financially and scientifically supported by the GENUS project.

## STUDY AREA

The Benguela upwelling system off southwest Africa is one of the four major eastern boundary coastal upwelling areas which are characterised by the ascent of cold and nutrient-rich waters from depths of 100 – 300 m to the sunlit surface over the continental shelf. Off the shore of Namibia, the coastal upwelling system extends from the coast to approximately 150 to 200 km offshore. The entire Benguela system is bounded by the Angola – Benguela Frontal Zone in the north and by the Agulhas Retroflexion zone in the south.

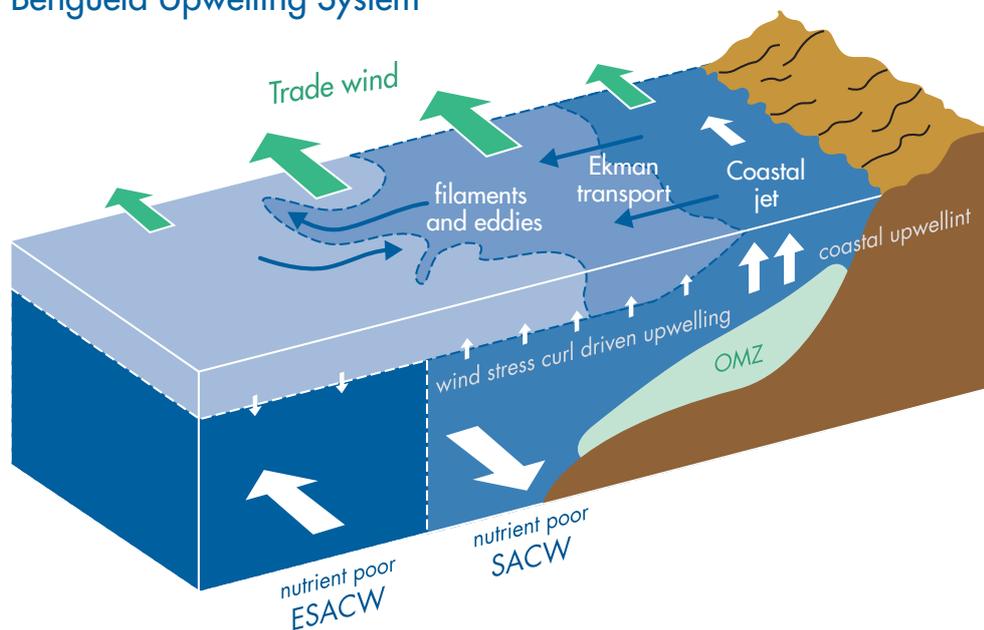


The food web structure in the northern Benguela upwelling region based on GENUS datasets

The upwelling system is one of the best examples of an ecosystem where coupling between hydrodynamic processes and primary production is tight. Relatively stable trade winds along the coast transport surface waters offshore and draw cold and nutrient rich water from the shelf edge at roughly 200 m water depth over the shelf and to the sea surface. An immediate expression of upwelling along the coast are cold water temperatures ( $<14^{\circ}\text{C}$ ), frequent fog, and dense clouds adjacent to the coastal desert. The upwelled mixture of water from intermediate water depths stems from two distinct sources: that from the north is old and thus rich in nutrients and  $\text{CO}_2$ , but poor in oxygen.

The water mass from the south is younger and more oxygenated, but poorer in nutrients and  $\text{CO}_2$ . The relative proportions of these two source waters in the upwelling water are essentially determined by the strength of the wind forcing, and in turn govern the oxygen and nutrient inventories in the northern Benguela System. Fast growing, microscopic siliceous algae (diatoms) are the dominant component of phytoplankton which in turn is the main nutrition base for small animals such as copepods and krill, the so-called zooplankton. The zooplankton biomass accumulates at a specific distance from the upwelling centres and downstream of the coastal belt of high phytoplankton stocks.

### Benguela Upwelling System



Schematic illustration of the ocean circulation in the GENUS working area

These regions with high zooplankton biomass are the preferred feeding grounds of juvenile anchovies and sardines, and also of abundant jellyfish that benefit from conditions in the upwelling system that are unfavourable for fish. With the copious fish resources (especially sardines) of the Benguela upwelling system yielding 10% of gross national product and being Namibia's third largest source of income, a shift in the dominating higher trophic levels towards, for example, jellyfish or commercially unviable fish species would have far-reaching economic consequences.

## SUBJECT OF RESEARCH

Scientific key aspects of the GENUS project are:

- › retrospective analyses of the physical boundary conditions and biogeochemical cycles
- › identification of key processes/species and analysis of key rates of physical, biogeochemical and biological ecosystem components
- › quantification and modelling of food web structure, feedback on changes of the food web, biogeochemical cycles and climate-related gases (CO<sub>2</sub>, oxygen, nutrients) in the upwelling region as well as in the adjacent ocean
- › simulations of interactions between shelf ecosystem – open ocean – atmosphere

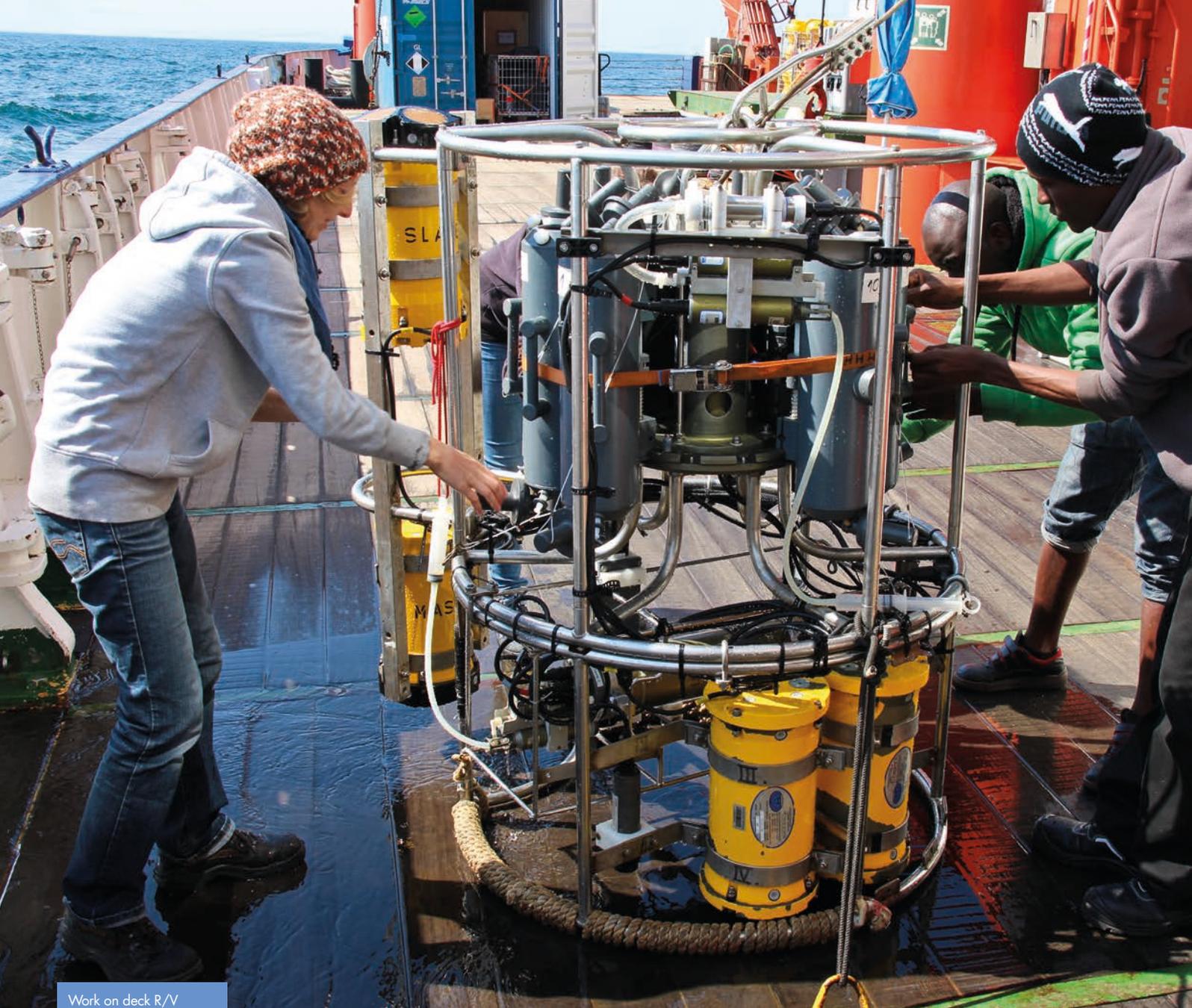
## KEY TO SUCCESS

The GENUS consortium comprises all relevant scientific disciplines for achieving the project goals and has all the intellectual and technical resources to successfully conduct an international research programme. The members of the project have established close cooperative relationships with scientists and regional scientific institutions in southwest Africa over the years and have collaborated successfully in previous national or bilateral projects in the region. These previous studies and ongoing cooperations have laid the ground for the scientific, educational and technical success of GENUS phases I and II.



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Work on deck R/V Meteor during M99 off Namibia

## SACUS – SOUTHWEST AFRICAN COASTAL UPWELLING SYSTEM AND BENGUELA NIÑOS

### BACKGROUND

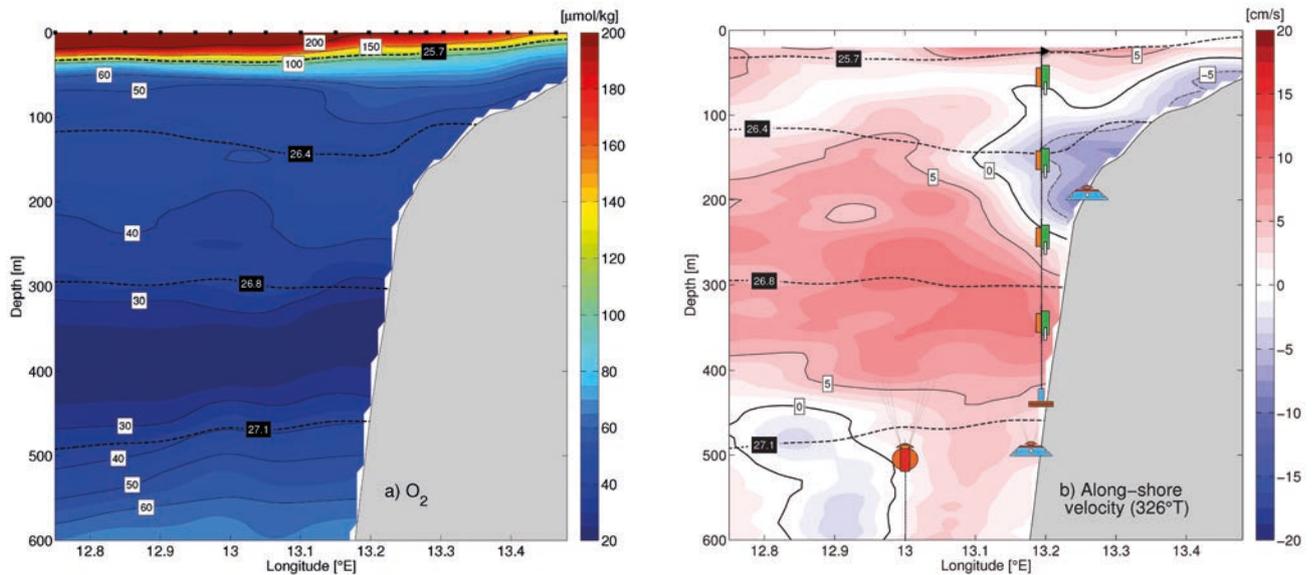
Coastal countries of southwest Africa strongly depend upon their ocean: societal development, fisheries and tourism face important changes associated with climate variability and global change. Global climate change will particularly impact eastern boundary upwelling regions of the tropical and subtropical

oceans through a combination of different stressors: increasing temperatures, acidification and deoxygenation. The understanding and prediction of regional ocean and climate variability is thus key in the cooperation between German and African partner institutes.

## OBJECTIVES AND RESEARCH APPROACH

The goal of the research project is an improved understanding of the physical mechanisms of regional climate variability and climate change with a profound impact on ocean biogeochemistry, hypoxia and marine ecosystems. These goals will be achieved by studying the local wind-driven upwelling variability, the wave propagation from the equatorial region and advection of water mass anomalies along the eastern boundary, and the impact of global climate change on the coastal ocean, as well as the ocean's role in the regional climate.

Dedicated observation systems, experiments at sea and various modelling approaches are applied in order to achieve an improved understanding of the intraseasonal to long-term changes of the southwest African coastal upwelling system and the overlying atmosphere to finally improve climate prediction for Southern Africa. The project aims to build and expand the local capacities required for the monitoring and prediction of the variability of the upwelling system and of the climate of surrounding land areas.



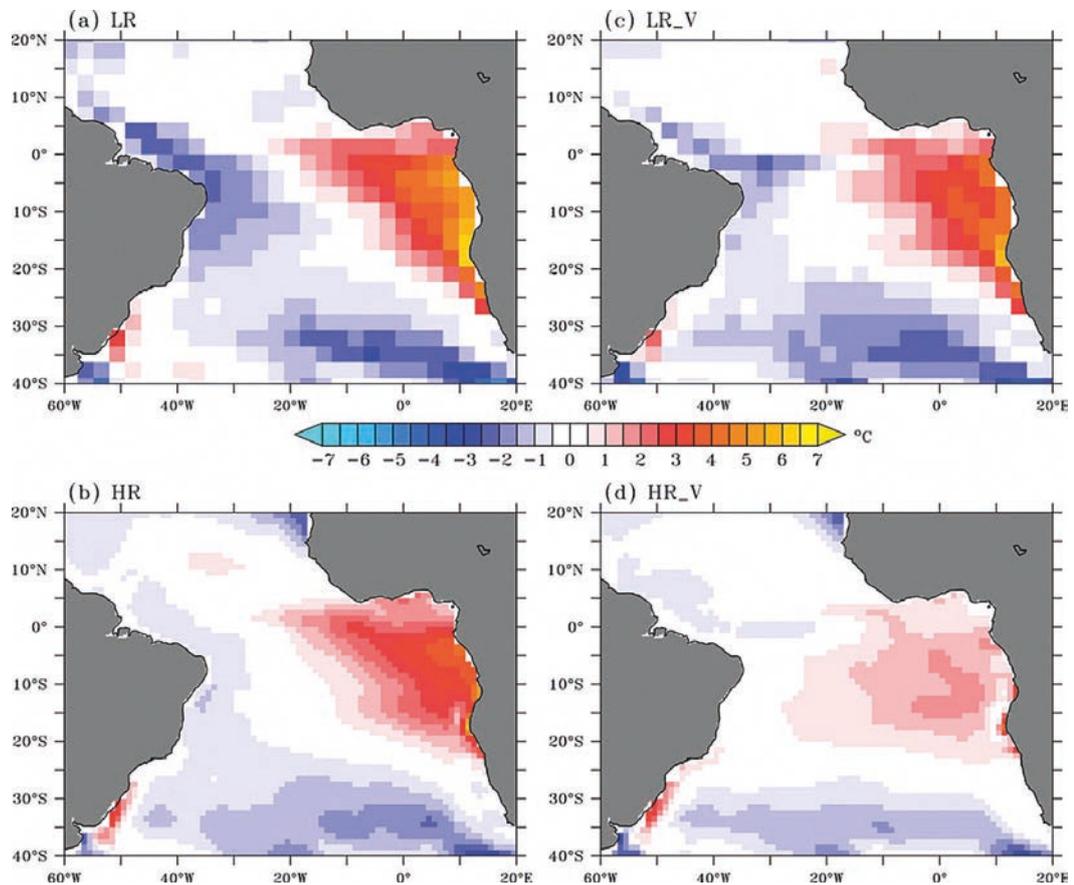
Dissolved oxygen concentration (a) and alongshore velocity (b) at ~11°S off Angola measured during R/V Meteor cruise 98 (chief scientist Peter Brandt). Schematic of moored instrumentation is superimposed in (b). The mooring array is equipped with three ADCPs, two ADCPs within bottom shields on the shelf at 200 m and 500 m depth and one ADCP at 500 m depth at 13 °E. The hydrographic mooring located at the shelf at a water depth of about 450 m measures temperature, salinity and oxygen at 350, 250, 150 and 50 m depth.

## STUDY AREA

The study area is the Southeast Atlantic including the coastal areas off Angola, Namibia and South Africa. To better understand local changes, we also consider data from the whole tropical Atlantic, particularly the equatorial Atlantic, and perform and analyse regional and global ocean and climate simulations.

## STRUCTURE AND PROJECT PARTNERS

The research topics of the project are studied within four subprojects (SPs). The focus of SP1 is the connection between the southwest African coastal upwelling system and the equatorial current system. Wave propagation from the equator and the advection of water mass anomalies are



Modern climate models show large biases in the tropical Southeast Atlantic, which can be reduced by increasing horizontal and vertical resolution at the same time. Bias in the sea surface temperature (°C) during boreal summer (July-August-September) in the Kiel Climate Model (KCM) relative to observations: a) low horizontal resolution, b) high horizontal resolution, c) low horizontal and high vertical resolution, d) high horizontal and high vertical resolution.

studied with respect to its influence on sea surface temperature and sub-surface oxygen. SP2 concentrates on observations and simulations of the variability of the eastern boundary current system off Namibia. The exchange between the eastern boundary current and the open ocean is the focus of SP3. Here the variability of upwelling and the formation of upwelling filaments are studied by observations and high-resolution ocean simulations. In SP4, the tropical Atlantic climate and its predictability are studied by using coupled ocean atmosphere models.

## PROSPECTS OF SUCCESS

Great progress could be achieved in all sub-projects regarding scientific questions, as well as regarding capacity building and development within the African partner institutes. Scientific progress could be reached with the installation and extension of the ocean observation system off Angola, Namibia and South Africa, as well as with the successful simulation of ocean and climate

variability. The importance of the research topics in the present project has also been recognised by the European Commission. Since November 2013, PREFACE has been funded by the European Commission's Seventh Framework Programme. PREFACE is a cooperative project with 28 partners across 18 countries in Europe and Africa and is directly involved in the sustainable management of the three eastern boundary large marine ecosystems of the tropical Atlantic. Cooperation and coordination of research between SACUS and PREFACE clearly enhances the prospects of success of climate research in the Southeast Atlantic.

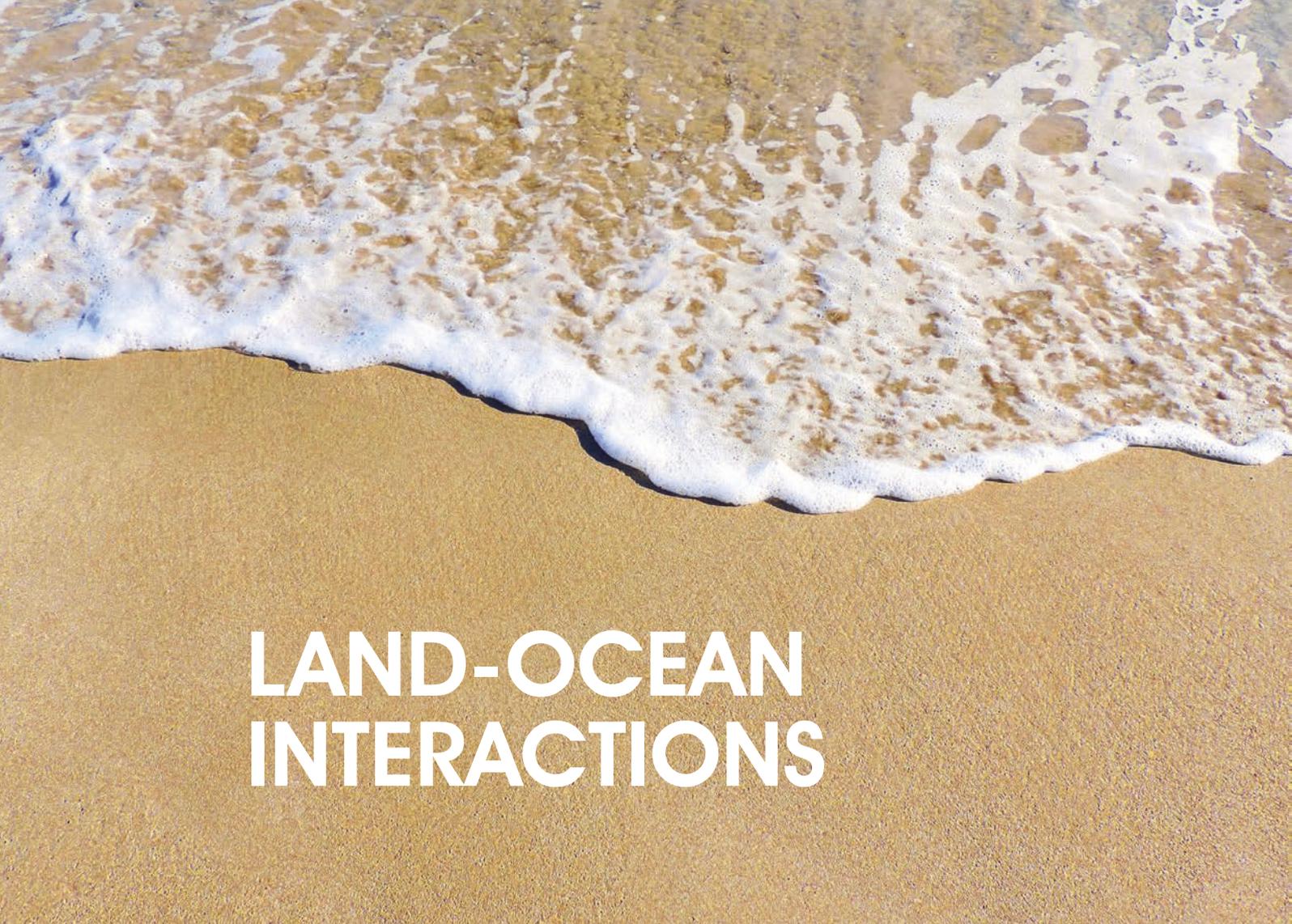


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Group photo of the scientific team of M100/2, which was particularly aimed at facilitating training, capacity building and knowledge exchange with students from Germany and the South African region.



# LAND-OCEAN INTERACTIONS

## **GSI – GROUNDWATER/SEAWATER INTERACTION ALONG THE SOUTH AFRICAN SOUTH COAST**

### **BACKGROUND**

Groundwater/seawater interaction (GSI), as a major form of ocean – land interplay, is associated with two potential pathways of dissolved material transport, namely (1) flux from the marine to the terrestrial environment caused by seawater intrusion into a terrestrial aquifer and (2) flux from a terrestrial aquifer to the coastal ocean manifested as submarine discharging groundwater. The sea-to-land pathway is of relevance (i) due to the risk of salinisation of coastal groundwater resources.

The land-to-sea pathway, on the other hand, is of concern due to two potential threats, namely (ii) the detrimental impact of nutrient or contaminant-laden groundwater discharge on the coastal water quality, an aspect that is of relevance along most coastlines worldwide, and (iii) the loss of freshwater to the ocean, an issue which is of particular interest in climate zones with (seasonally) limited groundwater recharge rates and thus limited freshwater availability. All of these aspects are of relevance in the project target area, the South African south coast.

## OBJECTIVES AND RESEARCH APPROACH

The project is set up as link between the terrestrial and the marine environments by applying a comprehensive approach using satellite data, remote sensing information, land use data, tracer distribution patterns in ground and seawater and marine biota data for the localisation and quantitative investigation of groundwater/seawater interaction and related processes. The approach will involve both the marine and the terrestrial perspective by investigating purely marine environments and marine/terrestrial interaction processes, as well as the vulnerability of coastal aquifers.

The approach will entail the multifaceted application and interpretation of a range of state of the art and innovative methodologies that go far beyond using standard parameters/variables and indicators for the assessment of risks related to coastal water quality, aquifer vulnerability and land use change. The results of the project will have high transfer potential to other regions in Southern Africa, thus encouraging further activities related to sustainable coastal water management.

## STUDY AREA

The project target area is the South African south coast. Characterisation and assessment of investigated GSI is based on previously selected representative target sites (Exemplary Study Areas – ESAs) along the South African south coast between False Bay and East London. Selected ESAs represent (1) a porous sandy aquifer (region of Strand/Gordons Bay, False Bay), (2) a fractured bedrock aquifer (region: Hermanus),



Geological units of the Table Mountain Group constitute the mountainous regions of the southwestern Cape and represent the most important fractured aquifer system of the area.

(3) an estuary affected by tides and tidal cycle (region: Knysna) as well as (4) an anthropogenically impacted coastal area (region: Strand/Gordons Bay; Port Elizabeth).

## SUBJECT OF RESEARCH

The main asset of the entire GSI project is the freshwater resources that are of major importance for the target area for the drinking water supply, process water and agricultural irrigation purposes. Further subjects of assessment and protection are ecosystem services of the coastal ocean and terrestrial soils. The setup of the scientific team assures that highly challenging problems can be addressed and solved on an interdisciplinary basis within the research group involved.



Distribution patterns of environmental tracers are mapped within the False Bay for submarine groundwater discharge (SGD) localisation. The Strand/Gordons Bay area was found to be the major SGD spot within the bay.

The entire project contains four different sub-projects (SPs). Based on the four distinct sub-projects, multifarious methodological approaches and techniques are applied. The methods include the analysis of remote sensing data and numerical modelling (SP1), the utilisation of environmental tracers (SP2), investigations of marine macrozoobenthos (SP3) and model-based assessment of land-use and land-use change (SP4).

The identification of potential submarine groundwater discharge (SGD) sites constitutes the main objective of SP1. This localisation procedure includes a terrestrial and a marine based approach. Since both techniques are aimed at a large spatial scale, applied approaches exploit remote sensing data (Landsat, ASTER, Hyperion, SRTM etc.) and likewise focus on a hydrogeological characterisation and numerical groundwater modelling of coastal zones for enabling aquifer vulnerability assessment.

The key objective of SP2 is a qualitative and quantitative SGD assessment within the four study areas. Environmental tracers that show distinct gradients at the groundwater/seawater interface (radon, radium, stable isotopes) are applied as SGD indicators. SP2 includes a terrestrial and a marine component: on the terrestrial side the focus is on groundwater (i.e. end-member) composition; on the marine side the focus is on mapping tracer patterns within the coastal sea.

SP3 aims to investigate and assess the effects of SGD as direct terrestrial impacts on the structure, function and biodiversity of benthic marine biota. If applicable, key species and/or characteristic communities will be identified and can be used as natural indicators for SGD occurrence.

The key objectives of SP4 are the assessment of groundwater vulnerability with respect to land use effects as well as the implementation of a coupled WebGIS/modelling system to simulate the effects of land use scenarios on coastal aquifers and related water resources at mesoscale.



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## RAIN – REGIONAL ARCHIVES FOR INTEGRATED INVESTIGATIONS

### BACKGROUND

The climate in Southern Africa is controlled by a very complex system of interrelations between different atmospheric and oceanic driving factors. On the one hand, the semi-arid southern Cape area frequently suffers from water scarcity and increasingly experiences problems related to decreasing water quality for crop production and drinking water supply for growing cities. On the other hand, in tropical eastern South Africa, heavy rainfall and flood events are already occurring more frequently and are predicted to increase in the future. The erosional and infrastructural damage caused by these events threatens the livelihood of millions along the densely populated South African east coast. In order to develop mitigation

strategies on a regional scale, it is necessary to accurately predict future climatic trends at a high spatial resolution. The comprehensive understanding of the climate system with all its components is therefore an essential prerequisite. For this purpose, a closer look at the climate history is one major key to improving existing knowledge. However, continuous, high-resolution climate archives recording the last tens of thousands of years are still extremely scarce in Southern Africa. Where these archives do exist, their interpretation is often vague or ambiguous as local or regional patterns are difficult to distinguish in this spatially highly variable climate.

Floating university onboard the research vessel METEOR, where German and South African scientists and students participate in the coring of marine archives off the shore of the Wilderness Lake system and along the western and eastern South African coastline during expedition M102 in December 2013.

## OBJECTIVES AND RESEARCH APPROACH

The joint South African German project RAIN aims to retrieve, compare and interpret high-resolution marine and terrestrial sedimentary climate archives from different locations throughout South Africa. This integration of indications for climate development from lacustrine and marine deposits is the scientific backbone of the RAIN project – a very innovative, not to say unique, approach. To strengthen the cooperation between South African and German scientists, capacity building is a further important objective of the project. Joint fieldwork and workshops, closely integrated lab investigations and ship expeditions are components of the programme, as well as research stays for young scientists in the partner country.

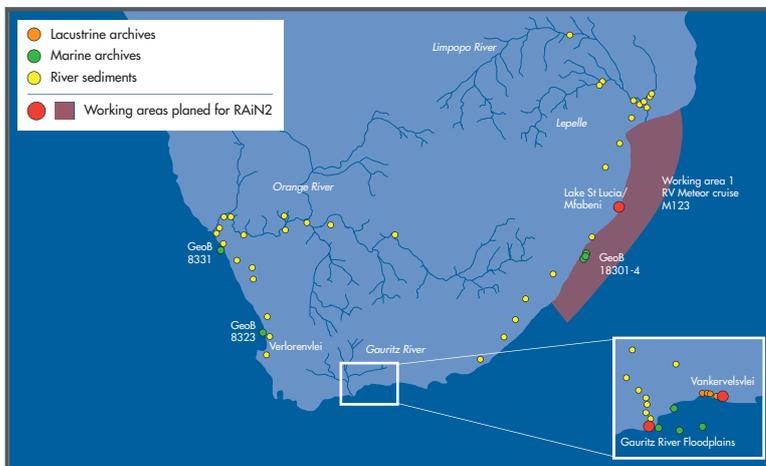
in the southwestern Cape area, receives its precipitation from northwards shifts in the westerly rainbelt occurring during the winter months. Additionally, our study areas are located at the interface of two major contrasting current systems: the cold Benguela to the west and the warm Agulhas current to the east, adding complexity to the precipitation variability in coastal areas. In order to gain a broad understanding of the regional climatic variability, terrestrial and marine study sites are strategically selected in the two main rainfall zones (the winter and the summer rainfall zones) as well as in the transitional zone located between them.

## SUBJECT OF RESEARCH

Several sea and land-based sampling and coring campaigns are conducted in the project. With a multidisciplinary approach, combining downcore inorganic/organic geochemical, sedimentological and paleontological analysis, a promising set of proxy parameters is determined.

## PROJECT STRUCTURE AND PARTNERS

The complexity and social-economic relevance of the research questions addressed by the RAIN project call for an integrative approach involving scientists from various scientific backgrounds as well as regional expertise. The German project partners (the universities of Jena and Bremen) have distinct focus areas forming four subject-oriented RAIN subprojects. These are strongly interlinked in all relevant aspects. The fifth subproject includes all capacity building initiatives. This has allowed the full integration of the South African project partners from diffe-



RAIN sampling locations since 2013 and planned working sites and areas for RAIN2.

## STUDY AREA

Most of South Africa receives its precipitation from Indian Ocean moisture influx via easterly trade winds during the summer months. However, the winter rainfall zone, located

rent universities and institutes (universities of Cape Town, Kwazulu-Natal and Witwatersrand as well as the Council of Geosciences).

## CHANCES OF SUCCESS/KEY TO SUCCESS

Essential prerequisites for the success of the RAIN project are the successful merging of findings from marine and terrestrial climate archives as well as the excellent cooperation between the South African and German partners. Within the first funding phase of RAIN, it has already been possible to understand the source to sink pathways of several marine and lacustrine records along the South African west and south coasts. In particular, a 30-metre-long, approximately 9,000-year-old record obtained from the Wilderness lake system has the potential to represent one of the longest, continuous, high-resolution South African climate records. Along the west coast, the combination of results from several marine cores and terrestrial samples could already improve the understanding of linkages between summer and winter rainfall zone shifts. During the second funding phase of RAIN, the focus will also include the easterly summer rainfall zone. Here, geoarchives in the Mfabeni peatlands and the Limpopo river and delta system will be the focus of investigations.



Research vessel METEOR



### CONTACT

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[www.marum.de/en/R\\_A\\_I\\_N.html](http://www.marum.de/en/R_A_I_N.html)



# CHANGING LANDSCAPES

## LIMPOPO LIVING LANDSCAPES (LLL) – DYNAMICS OF ECOLOGICAL AND CULTURAL LANDSCAPES

### BACKGROUND

Within South Africa, the dry Limpopo Province is particularly vulnerable to climate change (long-term) and human disturbance (short to medium-term). Habitat degradation and climate change are expected to have devastating consequences for land use and land cover change, biodiversity and associated ecosystem services.

### OBJECTIVES AND RESEARCH APPROACH

Limpopo Living Landscapes aims to understand and predict the combined effects of land use and climate change on (i) range-land vegetation and cropland, (ii) Limpopo's unique biodiversity as well as (iii) rural livelihoods and to identify farm and policy level intervention strategies that support sustainable rural livelihoods and the natural resource base on which these depend.

## STUDY AREA

The project performs detailed studies along two transects (from Thohoyandou to Giyani and from Polokwane to Phalaborwa), which provide a representative sample of climate, vegetation, soils, land use and rural communities of the Limpopo Province.

## SUBJECT OF RESEARCH

The methodologies include socio-economic assessments of the current and future livelihood options for rural communities, on-farm/on-station experimentation and measurement in agricultural systems with a focus on understanding crop productivity and rangeland dynamics under highly variable climates. Furthermore, remote sensing technologies and predictive modelling are used as tools for upscaling and extrapolation. By working within communities along these transects, scenarios will be developed participatively that explore better land management options under current and future climate scenarios. Limpopo Living Landscapes is divided into four subprojects:

### Subproject 1: Vegetation and rangeland dynamics and implications for policy

This project will use a dynamic vegetation model (the aDGVM) to develop land use strategies for Limpopo Province. First, a regional implementation of aDGVM will be developed to model the structural and functional diversity of the region. A second activity will have a policy focus and will explore how management options such as stocking rate, fuelwood extraction and fire suppression will interact with climate change to influence opportunities for different land use activities. The project will assess vegetation



Rainout shelters simulating a centennial-scale drought in the rangeland of Limpopo. Observed short and long-term effects of droughts help to increase our knowledge and understanding of rangeland dynamics under future climate conditions.

change and how key ecosystem services (e.g. carbon sequestration) will change with management and climate change. These findings will provide valuable scenarios of land potential cover change to inform policy.

### Subproject 2: Functional biodiversity in agricultural landscapes

This subproject will develop links between climate and vegetation parameters and functional attributes of animal communities, and assess consequences for ecosystem services. Based on their known sensitivity to environmental change, certain taxa (e.g. ants, dung beetles, bats, birds) are useful ecological indicators. Thereby, we extend traditional approaches that focus primarily on community composition by including examination of functional attributes. In particular, we will measure thermal

responses and behavioural interactions of ants in order to develop a mechanistic model of climate change impacts on ant biodiversity. Furthermore, we will quantify, via exclusion and dietary experiments, the value of different functional groups of animals for pest control and pollination to smallholder mango and commercial macadamia farmers.

### Subproject 3: Ecosystems and livelihoods

This sub-project will focus on the state of agricultural crops of smallholder farms, their ability to provide ecosystem services and their vulnerability under future global change including anthropogenic land transformation. The coupling of dynamic growth models with remotely sensed information on vegetation will enable us to make predictions on current and future land use patterns, hot spots and episodic events of degradation and its response to a wider range of climate scenarios. The link between socio-economic and ecological aspects will be at the centre of our research, including feedback from management on vegetation state and productivity.

### Subproject 4: Livelihoods and farming systems

This subproject will focus on strategies for achieving resilience in household food security and farm income. It aims to better understand crop and livestock-based processes and management options in the Limpopo area. For assessing functional interactions of the social-ecological systems at the current state and under projected climate and land use conditions, the sub-project will combine farm-based studies on crop and rangeland performance along steep natural gradients with controlled experimental studies. Field data will be integrated in plant (crop and rangeland)

and soil models coupled with climatic information to better understand the opportunities for increasing productivity and decreasing risk in crop and livestock farms in Limpopo. It will integrate climate and management to help crop and livestock farmers identify mitigation strategies towards undesirable future climatic conditions.

## PROJECT STRUCTURE AND PARTNERS

This is a collaborative project between universities in South Africa (Witwatersrand, Venda and Limpopo) and Germany (Göttingen, Bonn and Cologne, as well as Senckenberg Research Institute and Natural History Museum Frankfurt). An important feature is capacity building in the Limpopo Province.



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Ground truth measurements of ecosystem structure at savannah bushveld site, Skukuza, Kruger National Park, South Africa

# ARS AFRICAE – ADAPTIVE RESILIENCE OF SOUTHERN AFRICAN ECOSYSTEMS

## BACKGROUND

Nowadays, many semi-arid ecosystems are affected by at least two different kinds of disturbances: one is the strong influence of land use (in savannah ecosystems, very often the harvest of the woody biomass, but also cattle or sheep grazing) or land use change (mainly conversion to agricultural land); the second slower and often more indirect disturbance is climate change, caused by rising concentrations of greenhouse gases in the atmosphere. Based on such combined disturbances, it can be hypothesised that many ecosystems, even if they are very resilient, may not return to their initial state after disturbance, but will rather adapt to a new steady-state (e.g. associated with the intermediate change in climate). We name this phenomenon “adaptive resilience of ecosystems” and use it as basis for the research concept of ARS AfricaE.

## OBJECTIVES AND RESEARCH APPROACH

Early detection and action to prevent degradation in savannahs has been held back by the difficulty in making a clear distinction between „disturbance“ and „degradation“. In savannahs, for example, loss of woody biomass could in some cases be considered degradation, while in other cases an increase in woody biomass, for instance caused by rising CO<sub>2</sub>, could be considered degradation. This project wants to go beyond older approaches that only describe structural changes in savannahs (e.g. by species surveys, aerial photography, LIDAR) and their drivers (e.g. elephant density or fire in protected areas; overgrazing by cattle, charcoal production, land use change in unprotected areas). It employs on the one hand functional aspects, such as the investigation of biogeochemical cycles. On the other hand, it targets a deeper



Eddy covariance measurements at mopane site, Malopeni, Kruger National Park, South Africa

understanding of the functional consequences of ecosystem changes caused by multiple disturbances, and defines degradation as a sustained loss in the broad set of ecosystem services, i.e. a decrease in natural capital.

## STUDY AREA

Network of research clusters (paired sites with natural and altered vegetation) along an aridity gradient:

- › Greater Karoo, most arid cluster
- › Kruger National Park, intermediate precipitation cluster
- › Limpopo, high precipitation cluster

## SUBJECT OF RESEARCH

- › biogeochemical functions in combination with ecosystem structure, eco-physiological properties
- › ecosystem disturbance (and recovery) in terms of ecosystem function, such as carbon balance components and water use efficiency
- › prediction of ecosystem dynamics under (post) disturbance managements with individual-based models
- › combination with long-term landscape dynamic information derived from remote sensing and aerial photography
- › development of sustainable management strategies for disturbed ecosystems and land use change

## PROJECT STRUCTURE AND PARTNERS

The research project is a joint project involving four German and seven South African partner institutions. The German partners are Thünen Institute (Institute of Climate-Smart Agriculture), Goethe University Frankfurt (Department of Physical Geography) & Biodiversity and Climate Research Centre (BiK-F, Quantitative Biogeography), Friedrich-Schiller-University Jena (Department of Earth Observation) and Hamburg University of Applied Sciences (Department of Computer Science). The South African partners are the Council for Scientific and Industrial Research (Natural Resources and the Environment), University of Venda (Vuwani Science Resource Center), Stellenbosch University (Department Botany & Zoology), Grootfontein Agricultural Development Institute, Rhodes University

(Department of Computer Science), Forest Sense (Cape Town-based private company), and University of the Witwatersrand, School of Animal, Plant and Environmental Sciences (Wits Rural Facility).



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Participants of the ARS AfricaE kickoff meeting, Nov. 2014, Phalaborwa, South Africa. From rear left: Wolfgang Lück, Christian Brümmer, Eva Falge, Christiane Schullius, Bob Scholes, Azwitamisi Mudau, Ulfia Lenfers, Werner Kutsch, Simon Scheiter, Christian Hüttich, Kanisios Mukwashi, Wayne Twine, Victor Odipo. From front left: Karen Bradshaw, Thomas Thiel-Clemen, Tetukondjele Iiyambo, Guy Midgley

## IDESSA – DECISION SUPPORT SYSTEM FOR RANGELAND MANAGEMENT

### BACKGROUND

The increase in density of the woody savannah component is a common form of land degradation in South Africa with serious ecological and economic implications. The tree–grass ratio is determined by a range of interacting factors such as herbivory, fire and rainfall. Certain spatial and temporal combinations of these factors result in the suppression of the grass layer and promotion of woody growth. Related dynamics can be intensified by the regionally increasing atmospheric CO<sub>2</sub> levels. If land management does not accommodate these complex interrelated effects, savannah ecosystems lose resilience with a poorly reversible decrease in ecosystem functioning and productivity. At this stage, adaptive management, such as the sophisticated spatio-temporal distribution of livestock

or game and flexible stocking rates, are ineffectual, whereas natural self-thinning processes are far beyond an economically feasible time horizon. Accordingly, expensive restoration technologies need to be applied to control dense woody stands.

### OBJECTIVES AND RESEARCH APPROACH

The interplay of management and savannah dynamics is still not fully understood, particularly in the context of global change. Therefore, IDESSA aims to improve our understanding of these complex interactions and to implement an integrative monitoring and decision-support system for the sustainable

The maintenance of open and economically viable savannahs (left) and the appropriate combat of a densification of woody plants (right) requires knowledge of the short to long-term consequences of management strategies and control measures under varying climate scenarios.



management of savannahs in Southern Africa. In consideration of different environmental and land-use contexts, the system will provide an optimal means of taking management decisions to combat or mitigate increasing densities of woody plants in changing climatic conditions, both over the long-term and at short notice.

For this purpose, IDESSA follows an innovative approach that integrates local knowledge, botanical surveys, time-series of atmospheric and land-cover dynamics, spatially explicit simulation modelling and analytical database management. The integration of these heterogeneous data will be effected in a user-oriented database infrastructure and scientific-workflow system. Accessible via web-based interfaces, this database and analysis system will allow scientists to manage and analyse monitoring data and scenario computations, as well as allow stakeholders to retrieve current ecosystem information and seasonal outlooks.

## STUDY AREA

The decision-support system will be developed in reference to four core study areas that encompass different savannah types in South Africa. From east to west, these include mesic savannahs, transitions to woodlands and bush-encroached grasslands of KwaZulu-Natal province (Louwsburg area; MAP >700 mm), semi-arid savannahs in the North-West and Northern Cape provinces (Molopo and Kimberley area; MAP 300-500 mm) and arid savannahs of the Mier area (Northern Cape province; MAP <300 mm). Study sites therein cover different land-use types and management systems, including commercial game and cattle ranching, communal subsistence farming and conservation management in game reserves.



Field studies on local savannah dynamics support the ground-truthing of the satellite-based monitoring system for land-cover parameters and the validation of modelled vegetation responses to different land-use scenarios.

## SUBJECT OF RESEARCH

Research within IDESSA is coordinated within three interlinked subprojects, each addressing a specific component of the decision-support system:

Subproject 1 „Monitoring“ establishes a high-resolution, satellite-based monitoring system for past and present atmospheric (precipitation and temperature) and land-cover parameters. Multi-source remote-sensing data are linked to in situ observations using machine learning approaches. The developed models operationally generate time series of climate and woody densities across the study area. Updates of the time series are quasi-continuously processed and presented on an established IDESSA server.



Inadequate range management in arid Kalahari savannas results in the loss of perennial grass cover, causing an instability of dunes and favouring the densification of shrubs (here *Rhigozum trichotomum*) in dune streets. The avoidance of such developments depends on an improved understanding of the interactions of grazing and rainfall variability.

Subproject 2 „Management and Restoration“ develops a tool for testing the consequences of alternative savannah management and restoration options for vegetation development. The main component is a spatially explicit rangeland simulation model that identifies rules on how to manage savannas with a view to minimising the threat of increasing woody densities and improving the condition of the herbaceous layer.

Subproject 3 „Database and Analysis System“ develops an integrative analytical database serving as a central data repository and computation system that will assure both the immediate and long-term usability of the products of subprojects 1 and 2. As such, it will represent the IDESSA decision-support system, consisting of the following components:

1. A flexible database system allowing the efficient storage of and access to heterogeneous and multi-disciplinary datasets and related metadata information;

2. A visual data-mining and processing component allowing the computation and explorative analyses of the data derived from the atmospheric and land-cover monitoring, as well as facilitating the simulations of rule-based savannah dynamics;

3. A web-based user interface for (a) scientists to control their operational tasks and analyse scenario computations within a scientific workflow system, and (b) stakeholders to conduct contextualised, query-based retrievals. Visual analytics will support the visualisation of queries and scenario computations.

## PROJECT STRUCTURE AND PARTNERS

Subproject 1: Prof. Dr. Thomas Nauss (Philipps-Universität Marburg); subproject 2: Prof. Dr. Kerstin Wiegand (Georg-August-Universität Göttingen); subproject 3: Prof. Dr. Bernhard Seeger (Philipps-Universität Marburg). South African partners: Prof. Dr. Klaus Kellner (North-West University), Prof. Dr. David Ward (University of KwaZulu-Natal).



### CONTACT

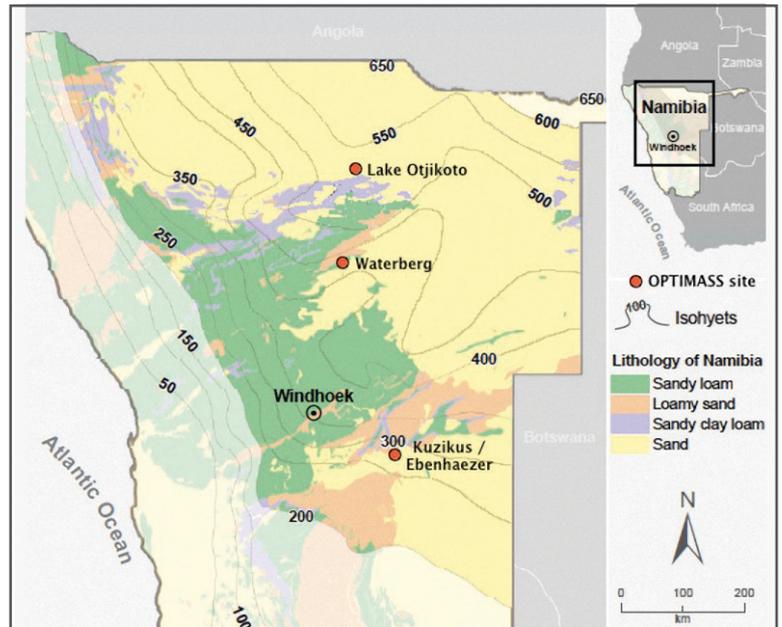
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# OPTIMASS – SUSTAINABLE MANAGEMENT OF SAVANNAH ECOSYSTEMS

## BACKGROUND

Savannahs of Africa support the livelihood of millions of households. Despite their regional and local relevance, these fragile ecosystems and the functions and services they provide are under particular threat. The key ecosystem services at risk include net primary production, water yield and quality, livestock production as well as wildlife, biodiversity and tourism.

Resource users and decision-makers in these regions face a number of challenges. They need to develop sustainable management options for livestock, wildlife and biodiversity under ongoing and predicted climatic changes (i.e. increasing temperatures, prolonged droughts and more extreme events) and increasing levels of atmospheric CO<sub>2</sub>. Previous research from the Namibian savannah region highlighted the threats due to climate change and unsustainable land use strategies that are ill-adapted to current and future conditions. Improving sustainability requires knowledge of the dynamic feedback between geosphere (soil, water, atmospheric CO<sub>2</sub> concentrations, climate) and biosphere (plants, animals) involved. Understanding the role of these complex links is crucial for the identification of management strategies that allow for an optimal use and maintenance of the desired ecosystem services.

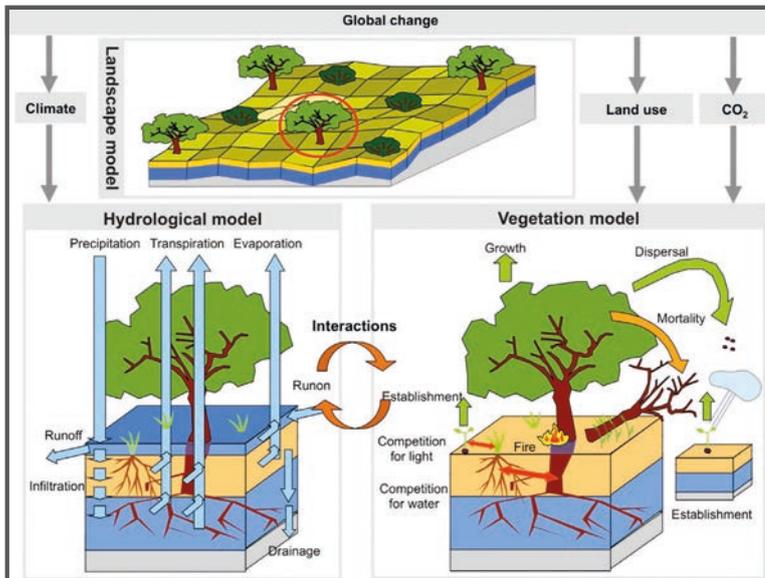


Location of the three OPTIMASS study sites at Lake Otjikoto, Waterberg National Park and Kuzikus Wildlife Reserve/Ebenhaezer Farm. The sites cover a precipitation gradient from approximately 270 mm to 540 mm of mean annual precipitation.

## OBJECTIVES AND RESEARCH APPROACH

Predicting possible transitions in savannahs as a basis for adapting and optimising management and restoration requires a mechanistic and process-oriented understanding of the major drivers and of their abovementioned feedback in particular. This is the research focus of OPTIMASS, a German–Namibian research project jointly coordinated by researchers at the universities of Potsdam and Namibia. Also including working groups from the Polytechnic of Namibia, the Eberhard Karls University

Tübingen, the Freie Universität Berlin and the Institute for Social-Ecological Research, the OPTIMASS team explores effects of land use and climate change on water, vegetation and biodiversity dynamics with specific attention given to feedback between geo- and biosphere. Therefore, OPTIMASS combines plant physiological, (palaeo-) ecological and hydrological field measurements with ecological experiments, stakeholder interviews and process-based computer models.



Eco-hydrological simulation model EcoHyD – process-based simulation models allow the integration of knowledge from different scales and disciplines and a projection of this knowledge to ecosystem level. Furthermore, an assessment of ecosystem dynamics under alternative land use and climate conditions is possible.

## STUDY AREA

OPTIMASS research focuses on three savannah study areas along a rainfall gradient in Namibia, covering a broad range of typical challenges for savannah drylands. Like in most other Southern African savannahs, the vegetation at these study

sites is partly degraded and shrub encroachment occurs. The most important encroaching shrub species are *Dichrostachys cinerea* and *Acacia mellifera*. Besides different soil types and precipitation values, the study sites also cover different land use types (i.e. game vs. cattle farming) and intensities.

## SUBJECT OF RESEARCH

OPTIMASS research covers key gaps in the current understanding of geo-biosphere feedback in savannah systems. This feedback is directly related to ecosystem stability and the sustainable provision of ecosystem services. Accordingly, continuous communication with stakeholders provides the basis for OPTIMASS research. In particular, the management of rangeland and water resources is assessed in stakeholder and expert interviews, which are subsequently integrated into socio-ecological participatory modelling approaches to reveal the most relevant scenarios of management and restoration.

In a holistic approach, OPTIMASS researchers assess the effects of climate and CO<sub>2</sub> concentrations on vegetation by combining greenhouse, climate chamber and common garden experiments. In addition, paleoecological analyses from pollen sediments taken from Lake Otjikoto disclose vegetation dynamics of the past and help to validate dynamic, process-based vegetation models. Further eco-hydrological field studies reveal the physiological response of different plant types to soil and groundwater dynamics under different land use and degradation scenarios while hydrological analyses quantify groundwater recharge and the sources for plant-available water. Biodiversity-related feedback is assessed by measuring vegetation

and soil – water dynamics in relation to the abundance of several key animal taxa, such as small mammals and beetles, along a land use and degradation gradient. Analyses include the quantification of effects of macropores created by ground dwelling insects on water infiltration and soil – water dynamics. Expanding the scope, experiments are conducted to assess the effects of potential ecosystem restoration measures, like reseedling of desired grass species or the application of fires considering dynamic geo-biosphere feedback.

Finally, the specific strength of the OPTIMASS approach is the combination of this broad set of empirical methods with eco-hydrological simulation modelling in order to assess the effects of different changes in land use and climate on the various feedback between geo and biosphere. These models enable a projection of the gained knowledge to broader temporal and spatial scales and to related ecosystems. They also build a reliable basis for the development of future scenarios and provide tools for the identification of sustainable management and restoration options supporting decision-making.



Joint fieldwork on biodiversity



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Drilling at Walvis Bay

## GEOARCHIVES – SIGNALS OF CLIMATE AND LANDSCAPE CHANGE PRESERVED IN SOUTHERN AFRICAN GEOARCHIVES

### BACKGROUND

In the context of global change, the Southern African region needs to address great challenges in terms of its natural resources, in particular to cope with the impact of climate and land-use change on the water balance, soil fertility and the quantity of land suitable for common requirements. Therefore, it is of the utmost importance to achieve more efficient resource utilisation and the preservation/availability of natural resources. Several cross-cutting issues must be considered to ensure sustainable and integrated resource and land management. Climatic changes or anthropogenic influences

such as farming, grazing and ploughing can degrade the landscape if its natural stability and its capacity potential are exceeded. This will directly cause sediment mobilisation and deposition. In order to fully understand the underlying processes of landscape evolution, it is necessary to open up archives suitable for the documentation of landscape evolution and climate change. In this context, natural archives in the landscape which provide information about the changing system conditions of the past are being sought, as written records for Southern Africa have only existed for some 300 years.

## OBJECTIVES AND RESEARCH APPROACH

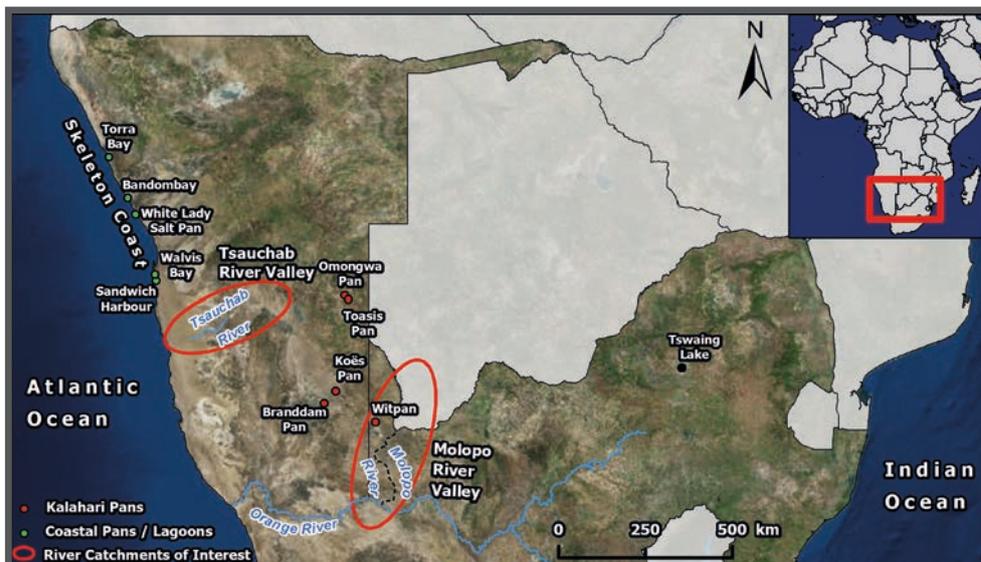
The central goal of GeoArchives is to open up and interpret geoscientific sources of information at the earth's surface (so-called geoarchives), which serve to characterise landscape evolution and climate change in Southern Africa. The investigation of geomorphodynamic sensitive landscape elements provides the potential to document changes of the land surface from local to regional scale with high resolution. In our target areas, a large variety of high-resolution geoarchives have been identified that formed within the timespan of the most recent decades, centuries and millennia (namely the youngest Quaternary, MIS 1-3). Together, these terrestrial and coastal geoarchives allow a deep insight into the climatic development and environmental conditions in Southern Africa during the warm Holocene period. We examine in particular slope sediments, alluvial fans and river terraces as well as lagoons and pans and use them as geoarchives.

The reconstruction of environmental changes is supplemented by remote sensing methods, which enable direct and indirect analysis of geoarchives and landscape elements at different spatial and time scales based on geochemical and physical parameters.

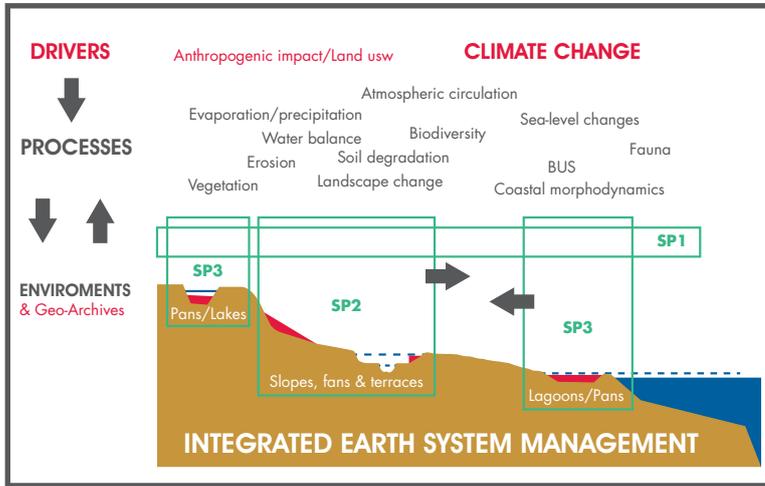
## STUDY AREA

The study areas are located in Namibia and the Republic of South Africa:

- › (Paleo-)Lagoons on the Namibian coast
- › Tsauchab Rv. (Namibia)
- › Pans in the Kalahari (Namibia and South African Republic)
- › Molopo Rv. (South African Republic)



Map of the investigation sites



Conceptual framework of GeoArchives; SP1 (remote sensing), SP2 (slopes, fans and terraces) and SP3 (salt pans and lagoons) denote the three work packages of GeoArchives

## SUBJECT OF RESEARCH

The investigation of specific sensitive environments in Southern Africa is carried out using coastal and terrestrial geoarchives of the Holocene with regard to the possible impact of future climate and land-use change. This allows us to provide future-oriented human habitat management with a geoscience rationale.

The project applies existing earth observation tools and develops new ones for earth system analysis in continental and coastal ecosystems in order to provide decisionmaking bases regarding adaption to global changes. The aim is to point out scenarios while considering past long-term developments which might occur as the consequence of future climate and land-use change impacts in Southern Africa.

## PROJECT STRUCTURE AND PARTNERS

GeoArchives is carried out by three research institutions (TUM, GFZ, SaM) and comprises three subprojects, each run jointly by two institutions. The highly interdisciplinary approach integrates geomorphology, soil science, sedimentology, inorganic and organic geochemistry, geomicrobiology and remote sensing.

Partners are located, for example, in the Republic of South Africa and Namibia.

Trench in the Toasis Pan



## KEY TO SUCCESS

Understanding the genesis and characteristics of the geoarchives analysed makes it possible to evaluate prognostic oriented scenarios and models based on real data. The results allow a qualitative and quantitative description of processes such as soil erosion, sedimentation and degradation at local and regional scales and thus provide indications of the possible future impact of land use, climate change and changing landscape.

The project contributes to closing gaps in knowledge that have an impact on the current and future development of use-sensitive regions in Southern Africa. These works have economic significance, as future changes in the study areas will in particular have an impact on the regional resources of soil and water and thus naturally lead to consequences for the valorisation and the future-oriented and environmentally friendly use of these regions. The land use (grassland management, breeding, wine-growing) is addressed as the central economic base in these regions.

Comparable work, in particular with regard to the overlapping areas of ubiquitously developed geoarchives and the link with remote sensing methods in a further step within the network, have not been carried out to date, meaning that a multitude of new scientific and practice-relevant results are expected that can be included in prognoses about future developments of African drylands.



Omongwa Pan with salt crust



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# SPACES CAPACITY BUILDING

Capacity Building comprises a major part of the SPACES programme. Apart from summer schools and workshops accompanying projects, BMBF together with DAAD (German Academic Exchange Service) initiated an associated scholarship programme.

Grants aim at the apprenticeship and advanced training of African students and young scientists, focusing on Environmental Sciences, Landscape Ecology, Geology and Oceanography.

The DAAD funded scholarships encompass three modules:

- › Master fellowships for Graduates (max. 24 months)
- › Research grants for Ph.D. students (max. 24 months)
- › Short term research grants for Graduates, Post-Graduates and Post-Docs (2-6 months)

Between 2011 and 2013 a total of 13 students were enrolled in the Master Scholarship Programme, 11 of them from Namibia and 2 from the Republic of South Africa (RSA); they completed their studies

in diverse Master programme at selected German universities:

## University of Bremen

- › International Studies in Aquatic Tropical Ecology
- › Marine Geosciences

## University of Kiel – Christian-Albrechts-Universität zu Kiel

- › Environmental Management

## Ernst Moritz Arndt University of Greifswald

- › Landscape Ecology and Nature Conservation

## Brandenburg University of Technology (BTU) Cottbus-Senftenberg

- › Environmental and Resource Management

A total of 9 research grants were provided for African Ph.D. students enrolled in Ph.D. scholarship programme, starting research in 2013 in 5 projects linked to the SPACES programme. An additional 5 short term research grants enabled African scientists to travel to Germany for on-site studies with their project partners.

## FLOATING ACADEMY FOR SCIENCE, EDUCATION AND TRAINING

Within the frame of the GENUS and RAIN research projects as well as research vessel transit legs, training cruises headed by experienced scientists were conducted for African students onboard German research vessels. Participating in research cruises, in 2011 a total of 33 African young researchers were trained by German scientists on „RV MARIA S. MERIAN“; in 2013 their number amounted to 32 on „RV METEOR“, and 21 were instructed in 2014 on „RV SONNE“. Another cruise with „RV METEOR“, carrying 14 students from African nations is scheduled for 2016. Training activities focus not only on scientific research dedicated to Physical Oceanography, Marine Biology, Marine Geology and Meteorology, but also encompass acquaintance of working processes, handling of measuring devices and life aboard a research vessel.



Scientific crew during the expedition SO 234/1 on RV SONNE



On-board training during the expedition on RV METEOR



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## Abc ABBREVIATIONS

aDGVM	adaptive dynamic global vegetation model
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVISO	Archiving, Validation and Interpretation of Satellite Oceanographic data
AWI	Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI)
FESOM	Finite-Element Sea Ice-Ocean Model
GEOMAR	GEOMAR Helmholtz Centre for Ocean Research Kiel
GFZ	Helmholtz-Centre Potsdam - GFZ German Research Centre for Geosciences
INIP	Instituto Nacional de Investigação Pesqueira
IOW	Leibniz Institute for Baltic Sea Research, Warnemünde
LIDAR	Light detection and ranging
MAP	mean annual precipitation
MFMR	Ministry of Fisheries and Marine Resources
MIS	Marine Isotopic Stage
NEMO	Nucleus for European Modelling of the Ocean
PREFACE	Enhancing prediction of Tropical Atlantic climate and its impacts
SaM	Senckenberg am Meer
SGD	Submarine groundwater discharge
SP	subproject
SRTM	Shuttle Radar Topography Mission
TUM	Technische Universität München
UCT	University of Cape Town
UNAM	University of Namibia
UNFCCC	United Nations Framework Convention on Climate Change

## APPENDIX: BASIC INFORMATION ON THE COLLABORATIVE PROJECTS

### AGULHAS – REGIONAL AND GLOBAL RELEVANCE

#### Coordination:

GEOMAR Helmholtz Centre for Ocean Research Kiel

#### Project partners:

- › Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven

#### International project partners:

- › University of Cape Town (Nansen-Tutu-Centre for Marine Environmental Research), Republic of South Africa
- › South African Environmental Network (SAEON), Republic of South Africa

### GENUS – GEOCHEMISTRY AND ECOLOGY OF THE NAMIBIAN UPWELLING SYSTEM

#### Coordination:

Universität Hamburg

#### Project partners:

- › Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven
- › Helmholtz-Zentrum Geesthacht, Centre for Materials and Coastal Research
- › Leibniz Institute for Baltic Sea Research Warnemünde
- › Leibniz Center for Tropical Marine Ecology, Bremen
- › Max Planck Institute for Meteorology, Hamburg
- › University of Bremen

#### International project partners:

- › University of Cape Town, Cape Town, Republic of South Africa Marine and Coastal Management, Cape Town, Republic of South Africa
- › National Marine and Information Centre (NATMIRC), Swakopmund, Namibia
- › Department of Environmental Affairs, Republic of South Africa

#### Website:

[www.genus.zmaw.de](http://www.genus.zmaw.de)

### SACUS – SOUTHWEST AFRICAN COASTAL UPWELLING SYSTEM AND BENGUELA NIÑOS

#### Coordination:

GEOMAR Helmholtz Centre for Ocean Research Kiel

#### Project partners:

- › Universität Hamburg, KlimaCampus
- › Leibniz Institute for Baltic Sea Research Warnemünde

#### International project partners:

- › NatMIRC, Ministry of Fisheries and Marine Resources, Swakopmund, Namibia
- › National Institute of Fisheries Research, Ilha do Cabo, Luanda, Angola
- › SANUMARC, University of Namibia
- › University of Cape Town, Republic of South Africa

#### Website:

[sacus.geomar.de](http://sacus.geomar.de)



### GSI – GROUNDWATER/SEAWATER INTERACTION ALONG THE SOUTH AFRICAN SOUTH COAST

#### Coordination:

Helmholtz Centre for Environmental Research – UFZ

#### Project partners:

- › Christian-Albrechts University of Kiel
- › Leibniz Institute for Baltic Sea Research, Warnemünde
- › Weihenstephan-Triesdorf University of Applied Sciences

#### International project partners:

- › CSIR – Council for Scientific and Industrial Research, Republic of South Africa
- › CGA – Centre for Geographical Analysis, Stellenbosch University, Republic of South Africa
- › UCT Marine Research Institute, University of Cape Town, Republic of South Africa
- › SANParks – South African National Parks, Republic of South Africa

#### Website:

[www.spaces-gsi.com](http://www.spaces-gsi.com)



## RAIN – REGIONAL ARCHIVES FOR INTEGRATED INVESTIGATIONS

### Coordination:

University of Bremen

### Project partners:

- › Friedrich Schiller-University Jena

### International project partners:

- › University of Cape Town, Republic of South Africa
- › University of KwaZulu-Natal, Durban/Pietermaritzburg, Republic of South Africa
- › University of the Witwatersrand, Johannesburg, Republic of South Africa
- › Council of Geosciences, Bellville, Republic of South Africa

### Website:

[www.marum.de/en/R\\_A\\_i\\_N.html](http://www.marum.de/en/R_A_i_N.html)



## LIMPOPO LIVING LANDSCAPES (LLL) – DYNAMICS OF ECOLOGICAL AND CULTURAL LANDSCAPES

### Coordination:

Georg-August-Universität Göttingen

### Project partners:

- › Rheinische Friedrich-Wilhelms-Universität Bonn
- › Universität zu Köln
- › Senckenberg Forschungsinstitut und Naturmuseum, Frankfurt am Main

### International Project partners:

- › University of Limpopo, Republic of South Africa
- › University of Venda, Thohoyandou, Republic of South Africa
- › University of the Witwatersrand, Johannesburg, Republic of South Africa

### Website:

[www.uni-goettingen.de/de/478267.html](http://www.uni-goettingen.de/de/478267.html)



## ARS AFRICAE – ADAPTIVE RESILIENCE OF SOUTHERN AFRICAN ECOSYSTEMS

### Coordination:

Thünen Institute for Climate-Smart Agriculture

### Project partners:

- › Hamburg University of Applied Sciences
- › Goethe University Frankfurt
- › Friedrich Schiller-University Jena

### International project partners:

- › Council for Scientific and Industrial Research, Natural Resources and the Environment (CSIR), Republic of South Africa
- › Stellenbosch University, Republic of South Africa
- › Grootfontein Agricultural Development Institute, South Africa
- › Rhodes University, Republic of South Africa
- › Forest Sense cc, Republic of South Africa
- › University of the Witwatersrand, Republic of South Africa

### Website:

[www.ars-africae.org](http://www.ars-africae.org)



## IDESSA – DECISION SUPPORT SYSTEM FOR RANGELAND MANAGEMENT

### Coordination:

Georg-August-Universität Göttingen

### Project partners:

- › Philipps-Universität Marburg

### International project partners:

- › North-West University (Potchefstroom Campus), Republic of South Africa
- › University of KwaZulu-Natal, Republic of South Africa

### Website:

[www.idessa.org](http://www.idessa.org)



## OPTIMASS – SUSTAINABLE MANAGEMENT OF SAVANNAH ECOSYSTEMS

### Coordination:

University of Potsdam

### Project partners:

- › Freie Universität Berlin
- › Eberhard Karls University Tübingen
- › Institute for Social-Ecological Research (ISOE), Frankfurt/Main

### International project partners:

- › University of Namibia, Windhoek, Namibia
- › Polytechnic of Namibia, Windhoek, Namibia

### Website:

[www.optimass.org](http://www.optimass.org)



## GEOARCHIVES – SIGNALS OF CLIMATE AND LANDSCAPE CHANGE PRESERVED

### Coordination:

Technische Universität München

### Project partners:

- › Helmholtz-Centre Potsdam - GFZ  
German Research Centre for  
Geosciences
- › Senckenberg am Meer,  
Wilhelmshaven, Senckenberg  
Nature Research Society

### International project partners:

- › University of Namibia, Windhoek,  
Namibia
- › University of Cape Town, Republic  
of South Africa

### Website:

[www.geomorphologie.wzw.tum.de/  
index.php?id=62](http://www.geomorphologie.wzw.tum.de/index.php?id=62)

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