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SPACES II – SCIENCE PARTNERSHIPS FOR THE ADAPTATION TO COMPLEX EARTH SYSTEM PROCESSES IN SOUTHERN AFRICA

The interactions between geosphere, biosphere, atmosphere and ocean are in the focus of the research programme SPACES.

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SPACES II

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Sustainable Development Goals (SDGs) of the United Nations.

INTRODUCTION

One of the greatest challenges of the 21st century is that of climate change. Ongoing global warming, increasing frequency of extreme weather events with storms, heavy rainfall or lasting droughts, associated soil erosion as well as melting glaciers, changing ocean circulations and sea-level rise threaten not only vegetation and wildlife, but also our habitats, health and food security. Developing countries are generally the most affected by climate change. The people there are often directly dependent on natural resources for their livelihoods and have only limited access to the resources needed to adapt to climatic changes. Furthermore, anthropogenic influences such as intensive land use, aquaculture and environmental pollution present severe consequences for the environment.

Climate change no longer concerns science alone; this topic rests in the heart of our society. Worldwide initiatives, such as the movement "Fridays for Future" founded in 2018, demand rethinking and specific measures for a more effective climate protection.

Climate change and global change are also central topics of the Agenda 2030 passed by the United Nations in 2015: All countries have strived to achieve the 17 Sustainable Development Goals (SDGs) since 2016. Two of these goals in particular have a central meaning for the preservation of natural habitats: SDG 14 "Life below water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development" and SDG 15 "Life on land: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reserve land degradation, halt biodiversity loss".

The African continent is facing the greatest pressures due to inevitable climate change. Furthermore, the implications and impacts of global change such as the competition for raw materials, food scarcity and associated land-use conflicts are particularly critical. In its resolutions, the international community has demanded support for developing and emerging countries in the adaptation to climate change; in

addition, numerous African countries and the African Union have identified areas of potential activity.

Within the framework of the Scientific and Technical Cooperation with countries in southern Africa, the Federal Ministry of Education and Research (BMBF) initiated and funded the programme "Science Partnerships for the Assessment of Complex Earth System Processes in Southern Africa" (SPACES) commencing in 2012 and running until 2018. Scientists from German universities and extramural research institutions together with South African, Namibian and Angolan partners have investigated the interactions between ocean, atmosphere, geosphere and biosphere (see brochure about SPACES, first phase).

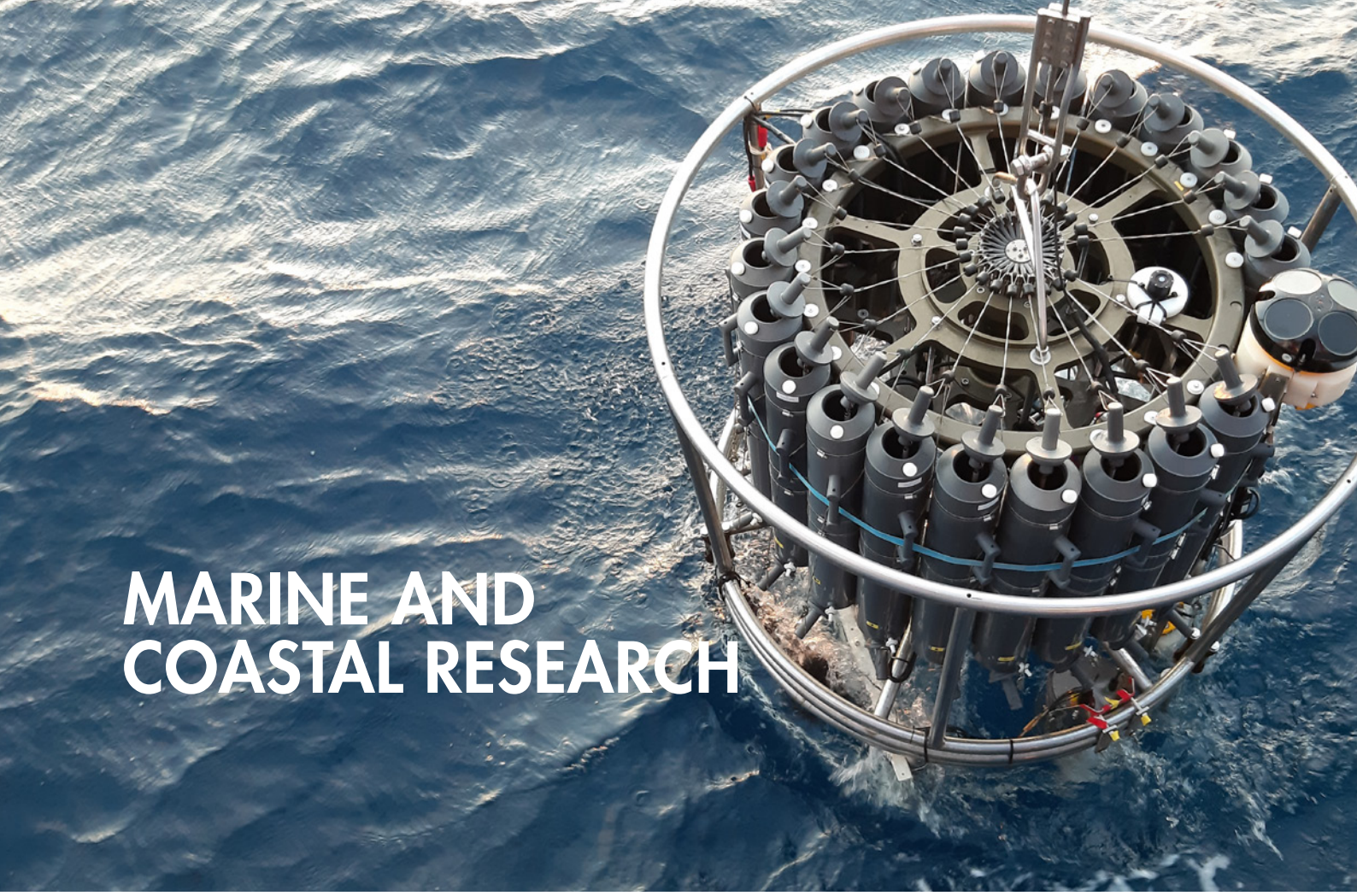
In the second phase of the research programme (SPACES II), the focus moves to the adaptation to the complex processes, to management options and specific recommendations for action for policy and society. The cooperation of scientists from Germany, South Africa, Namibia, Angola, Mozambique, Malawi and Zambia has the following focal points:

- seasonal and interannual variability and trends of coastal current systems around southern Africa, their influence on land-ocean-atmosphere interactions and on biogeochemical cycles as well as the management of marine resources
- transport of water, carbon, nutrients and pollutants, considering their transformation mechanisms in rivers, estuaries and coastal areas as well as their importance for the population, biodiversity and ecosystem services
- functioning of multiple-use landscapes regarding sustainable land use, land-use changes, carbon and water fluxes as well as their impacts on biodiversity, habitats and ecosystem services
- management options for multifunctional landscapes, for the formation of ecosystems and for the strengthening of societal resilience to environmental change
- development and implementation of measures for the restoration and sustainable use of degraded ecosystems with the goal of adaptation, resilience and mitigation

This brochure presents the nine collaborative projects which conduct research on the aforementioned topics within the framework of SPACES II running from 2018 until 2021. These are accompanied by a project supporting junior scientists by means of scholarships and summer schools.

The German project partners are funded by the BMBF and overseen by Project Management Jülich (PtJ) and the DLR Project Management Agency (DLR-PT). The South African and Namibian partners are supported by the South African Department of Science and Innovation (DSI), the Namibian Ministry of Higher Education, Technology and Innovation (MHETI) as well as the Namibian National Commission on Research, Science and Technology (NCRST).

SPACES II
Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa



MARINE AND COASTAL RESEARCH

BANINO–BENGUELA NIÑOS: PHYSICAL PROCESSES AND LONG-TERM VARIABILITY

BACKGROUND

The coastal waters along the South-West African countries are part of the Eastern Boundary Upwelling Systems (EBUS). They host a highly productive ecosystem supporting a coastal population living in tropical to subtropical climate zones. This marine ecosystem plays a key socio-economic role for societal development, fisheries and tourism. EBUS face significant changes associated with climate variability and global warming. The impact of climate change on EBUS regions is not fully understood and assumed to be complex, due to the different and interacting effects of increasing temperatures, acidification and deoxygenation. Local and remote forcing of ocean variability plays a crucial role in shaping the conditions in the South-West African EBUS and they must be considered in attempt to predict the climate in that region. This requires a continuous improvement of numerical model systems and their validation against observations. However, the coastal observing system of the South-West African EBUS is not well developed; its improvement is a primary goal of the international research community. The collaboration between German and African institutions is thus crucial to understand the processes driving coastal upwelling and high biological productivity in the South-West African EBUS, which is the focus of this project.

OBJECTIVES AND RESEARCH APPROACH

The goals of this research project are to enhance the database and improve the understanding of the South-West African EBUS using ocean observations as well as forced ocean and coupled climate models. The research is aimed at improving the prediction of climate variability and impacts of climate change as well as investigating poorly understood processes relevant for upwelling variability and its consequences for

biological productivity. We will study the wind-stress forcing over the South-West African EBUS, including large-scale and local alongshore wind stress and curl, tidally-generated internal waves, induced mixing on the shelf affected by riverine fresh-water input and precipitation, frontal dynamics at the Angola-Benguela frontal zone as well as the role of stratification within the boundary-current region on the development of Benguela Niño events. Observations and modelling are applied to study the South-West African EBUS variability on time scales from sub-seasonal to decadal and the overlying atmosphere to enhance climate prediction for southern Africa. Developing the cooperation between German and African partner institutions by enhancing the local capabilities in ocean observing, numerical modelling and data analysis is the aim of this project.

STUDY AREA AND METHODS

The South-East Atlantic Ocean encompassing the areas off Angola, Namibia and South Africa is the study area of interest. Data collected from all areas of the tropical Atlantic Ocean, particularly the equatorial Atlantic, will help to better understand local changes in climate and ecology, to perform and analyze regional and global ocean and climate model simulations. Field experiments are carried out including shipboard observations, the use of autonomous gliders and the maintenance of long-term moorings. In-situ data acquired within the project are analyzed in comparison to other datasets including remote-sensing satellite and Argo-float data. Results from data analysis are synthesized with output from high-resolution ocean and climate models. Specific model simulations are analyzed with regard to process and climate variability in the South-East Atlantic Ocean.

ACTIVITIES AND EXPECTED OUTCOMES

Ocean observations and modelling will particularly focus on Benguela Niño and Niña, events that are characterized by anomalously warm and cold coastal sea surface temperature (SST), respectively (Fig. 1). Our findings suggest that most of the extreme events are associated with the propagation of equatorial Kelvin waves along the equatorial waveguide, which trigger poleward-propagating coastally trapped

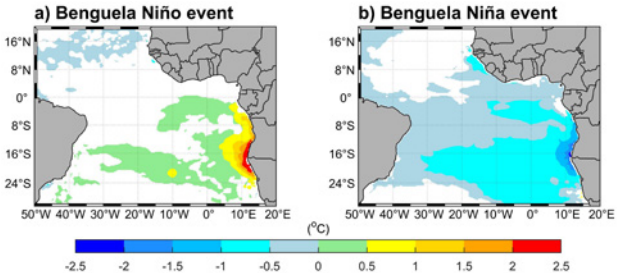


Fig. 1: Composite maps of temperature anomalies at 10 m depth from an Ocean General Circulation Model showing the signature of a) Benguela Niños and b) Benguela Niñas in the South-East Atlantic.

waves along the southwestern African coast. One to two months before the peak season of the anomalous coastal events (usually March to April), a large-scale surface wind pattern is observed, encompassing both variations of alongshore coastal winds over the southeastern Atlantic and zonal winds along the equatorial Atlantic.

The SST exhibits a strong variability at interannual time scales in the Angola-Benguela Area (ABA, 8°E to the coast; 10°S-20°S), with maximum variability during March-May (MAM), the season when most of the Benguela Niños/Niñas occur. However, a strong multidecadal reduction of the interannual SST variability occurred in the ABA in MAM in the post-2000 period (2000–2017) relative to the pre-2000 period (1982–1999); (Fig. 2).

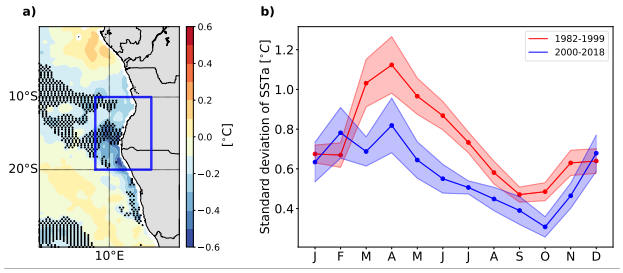


Fig. 2: a) Difference between 2000–2018 and 1982–1999 March-May standard deviation of sea surface temperature anomalies (SSTa).
b) Ensemble-mean standard deviation of SSTa averaged over the Angola-Benguela area (blue box in a) as function of the calendar month: 1982–1999 (red) and 2000–2018 (blue) calculated for different SST datasets (shaded).

PROJECT STRUCTURE AND PARTNERS

The research questions of the project are studied within four subprojects (SPs). The focus of SP1 is on observations and data analysis regarding the tropical Angolan upwelling system. SP2 investigates the physics of upwelling and warm events in the northern Benguela upwelling system off Namibia.

Investigating the relevant physical processes responsible for the temporal and spatial variability of the Benguela upwelling system using in-situ data, remote-sensing and high-resolution ocean modelling is the focus of SP3. Finally, SP4 focuses on the relationship between the mean state of the southeastern tropical Atlantic Ocean and the characteristics of Benguela Niño events.

Group picture of the scientific crew of Meteor cruise M158 during September/October 2019.

BANINO Spaces II

BANINO – BENGUELA NIÑOS: PHYSICAL PROCESSES AND LONG-TERM VARIABILITY

COORDINATION:

GEOMAR Helmholtz Centre for Ocean Research Kiel

CONTACT:

Prof. Dr. Peter Brandt
pbrandt@geomar.de

GEOMAR Helmholtz Centre for Ocean Research Kiel
Düsternbrooker Weg 20
24105 Kiel, Germany

PROJECT PARTNERS:

- Leibniz Institute for Baltic Sea Research Warnemünde (IOW)
  Rostock, Germany
- Universität Hamburg:
  Center for Earth System Research and Sustainability,
  Institute of Oceanography
  Hamburg, Germany
- Instituto Nacional de Investigaçaõ Pesqueira
  (National Fisheries Research Institute; INIP)
  Luanda and Namibe, Angola
- National Marine Information and Research Centre (NatMIRC)
  Swakopmund, Erongo, Namibia
- Gobabeb Research and Training Centre
  Gobabeb, Walvis Bay, Namib-Naukluft Park, Namibia
- University of Cape Town (UCT):
  Department of Oceanography
  Cape Town, South Africa

WEB PAGE:

www.banino.geomar.de/index_en.html

TRAFFIC – TROPHIC TRANSFER EFFICIENCY IN THE BENGUELA CURRENT

BACKGROUND

Along the west coasts of the continents, nutrient-rich water wells up due to the wind systems prevailing there and it causes a high phytoplankton production. This is followed by high zooplankton and fish productivity. These coastal upwelling areas produce about 20 percent of the annual fish landings and thus play a significant role in the food supply of the world population and in the carbon and nutrient turnover in the ocean. The Benguela upwelling area off the coasts of South Africa, Namibia and Angola is one of these highly productive coastal upwelling systems. However, the high phytoplankton productivity in this area is in surprising contrast to the low productivity of the higher trophic levels compared to other upwelling systems such as the Humboldt Current off Peru. Nutrients that reach the surface during upwelling are apparently exported again quickly, so that organisms of the higher trophic levels cannot effectively exploit the available primary production. The consequence of this inefficient recycling of nutrients is that, despite short trophic paths, the biomass of all zooplankton in the northern Benguela system is close to the global average of only 1.3–1.8 grammes carbon per square metre and fishing yields in 2006 were only about 0.42 million tonnes. In the upwelling area off Peru, the yield in the same year was more than ten times higher at 6.8 million tonnes with fishing areas of similar size.

OBJECTIVES AND RESEARCH APPROACH

Changes in the South-East Atlantic over the last decades have also altered ecosystem services, with different consequences in the northern and southern Benguela Upwelling System (nBUS, sBUS). In addition to fisheries, also the CO_2 uptake is affected. In order to understand the mechanisms of these changes and impacts and to obtain a better prediction of the future behaviour of the ecosystem and thus the provision of its services, TRAFFIC is conducting fundamental research on the processes of the subsystems nBUS and sBUS and their responses to climate change.

Young scientists: Exchange of a part of the young researchers during Meteor trip M153 to allow more young scientists to participate.

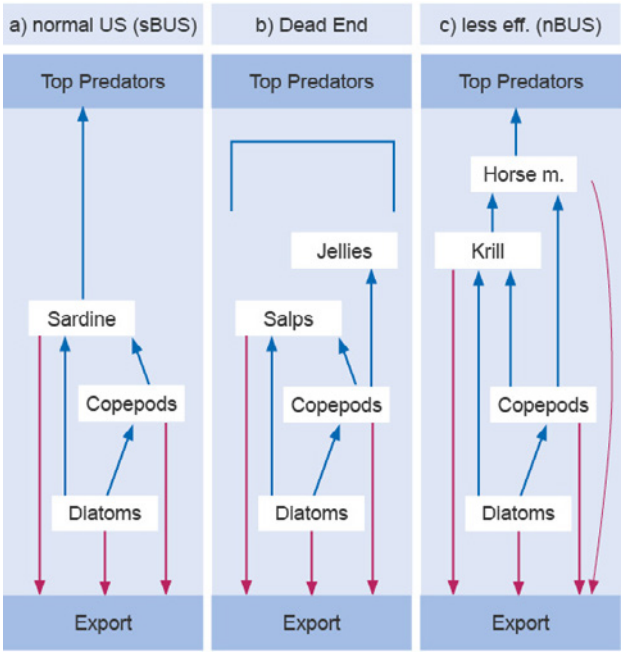


Fig. 1: The three potential scenarios to be tested for the structure of the trophic systems in the northern and southern Benguela Upwelling Areas.

Three potential scenarios in the trophic systems of the nBUS and sBUS are conceivable and shall be tested: 1) the classic upwelling ecosystem with small pelagic species (sardines) in central function (Fig. 1a), as still largely found in the sBUS, 2) a completely restructured ecosystem in which jellyfish and salps are dead ends in the food chain (Fig. 1b) as well as 3) a system that is less productive where sardines are replaced by krill and horse mackerel (Fig. 1c). One research cruise each in southern summer and winter in the nBUS and sBUS are carried out.

TRAFFIC thus addresses objectives 4 and 5 in the FONA-SPACES programme for proposals on the "Adaptation to Complex Earth System Processes in Southern Africa". The strategy „Research for Sustainability" (FONA) has set itself the goal of protecting common goods such as climate, bio-diversity, land and seas.

Capacity development is a major concern of TRAFFIC and is carried out in the form of master's (MSc) and doctoral (PhD) theses as well as on-board training during the research cruises.

STUDY AREA AND METHODS

The Benguela upwelling system off South-West Africa comprises a coastal upwelling zone of approximately 150 to 200 kilometres width. Enclosed between two warm water currents, the Angola Current in the north and the Agulhas Current in the south, the Benguela upwelling system is divided into two very different subsystems by the very strong upwelling cell off Lüderitz (Fig. 2): The northern part is dominated by the South Atlantic Central Water (SACW), which is accompanied by a pronounced oxygen minimum zone, while the southern part is influenced by the Eastern South Atlantic Central Water (ESACW). While the SACW in the north is rich in nutrients and CO_2, the ESACW in the south is comparatively poor in nutrients and CO_2. This leads to different food-web structures and productivity. Since primary production in both subsystems is very similar, these relationships indicate a more efficient use of nutrients in the sardine-dominated south.

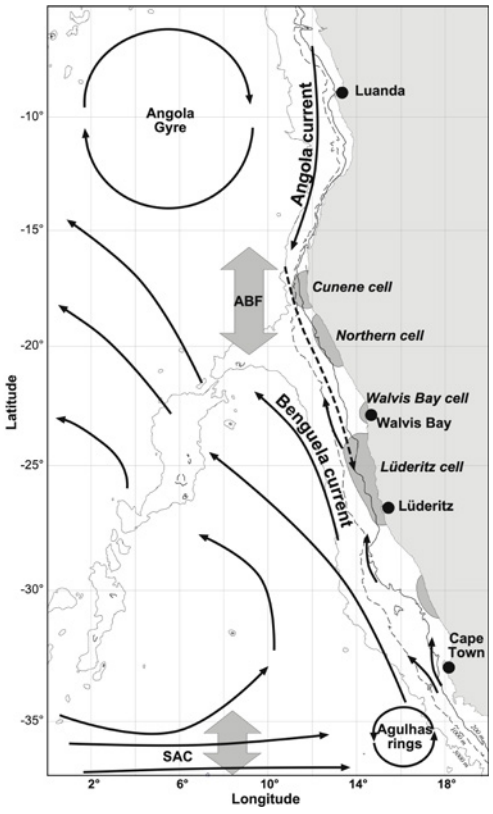


Fig. 2: The study area of TRAFFIC: the Benguela Current Upwelling System off Namibia and South Africa.

ACTIVITIES AND EXPECTED OUTCOMES

TRAFFIC benefits from the long-lasting trilateral cooperation in all sub-projects. Decisive data bases used in TRAFFIC have been developed in GENUS (Geochemistry and Ecology of the Namibian Upwelling System) and other predecessor projects (BENEFIT, WTZ, Namibgas) and will be supplemented within the framework of TRAFFIC. Especially in the southern Benguela system, studies on the physiology and condition of some key pelagic organisms are lacking.

TRAFFIC will use two international and interdisciplinary research cruises for this purpose: a cruise with research vessel RV Meteor already carried out in 2019 and a second cruise with RV Sonne in 2021. In addition, individual sampling with the South African R Africana and the Namibian research vessel R Mirabilis is planned in order to also deploy mooring systems for continuous recording of carbon exports.

The results of the TRAFFIC investigations will be directly translated into recommendations for management by the project partners Department of Forestry, Fisheries and the Environment (DFFE; formerly DAFF and DEA) and NatMIRC in South Africa and Namibia, who are conducting their research as part of their fisheries and environmental management tasks. TRAFFIC's participation in regional research forums, such as the Science Forum of the Benguela Current Convention (BCC and the South African Marine Science Symposium (SAMSS)), are therefore important activities.

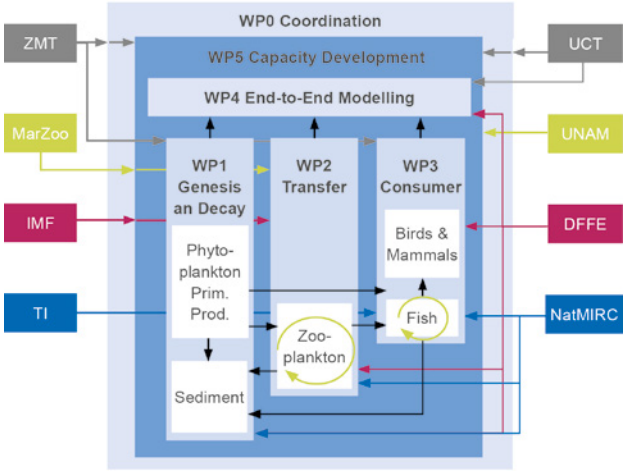
In order to strengthen the research partners, TRAFFIC will be involved in capacity development at the cross-network level. The integration of MSc and PhD candidates from Germany, Namibia and South Africa is firmly planned in all subprojects. Summer schools and contributions to MSc programmes will be organised.

The investigations in TRAFFIC will contribute to improve our knowledge of the ecological processes in the northern and southern Benguela upwelling systems to better under-stand the complex trophic systems and their interactions with fisheries and climate as well as to model them. Based on the results obtained in the project, fundamental knowledge can be gained for science, politics and society to develop management plans for sustainable ecosystem services.

PROJECT STRUCTURE AND PARTNERS

The project consists of three scientific work packages that map different levels of trophic activity: 1) production and sedimentation processes, 2) primary consumption level consisting mainly of zooplankton as the central converter of energy and biomass as well as 3) the level of higher consumers with mainly fish and warm-blooded animals. Partners from Germany and southern Africa are working together on the different research questions in the work packages.

The Leibniz Centre for Tropical Marine Research (ZMT) is responsible for the overall coordination of the project, which consists of five subprojects assigned to different institutes. In addition, four German institutes and five institutes from southern Africa are involved.



Work packages and partners in TRAFFIC.

TRAFFIC – TROPHIC TRANSFER EFFICIENCY IN THE BENGUELA CURRENT

COORDINATION:

Leibniz Centre for Tropical Marine Research (ZMT)

CONTACT:

Dr. Werner Ekau
werner.ekau@leibniz-zmt.de

Leibniz Centre for Tropical Marine Research
Fahrenheitstraße 6
28359 Bremen, Germany

PROJECT PARTNERS:

- University of Bremen:
  Center for Research and Education (BreMarE):
  Bremen, Germany
- University of Hamburg:
  Institute for Marine System and Fishery Science (IMF)
  Hamburg, Germany
- University of Hamburg:
  Institute for Geology (IFG)
  Hamburg, Germany
- Johann Heinrich von Thünen:
  Institute of Sea Fisheries (TI-SF)
  Bremerhaven, Germany
- University of Cape Town (UCT)
  Cape Town, South Africa
- Department of Forestry, Fisheries and
  the Environment (DFFE)
  Cape Town, South Africa
- Ministry of Fisheries and Marine Resources (MFMR)
  Windhoek, Namibia
- National Marine Information and Research Centre
  (NatMIRC)
  Swakopmund, Erongo, Namibia
- University of Namibia (UNAM)
  Henties Bay, Namibia

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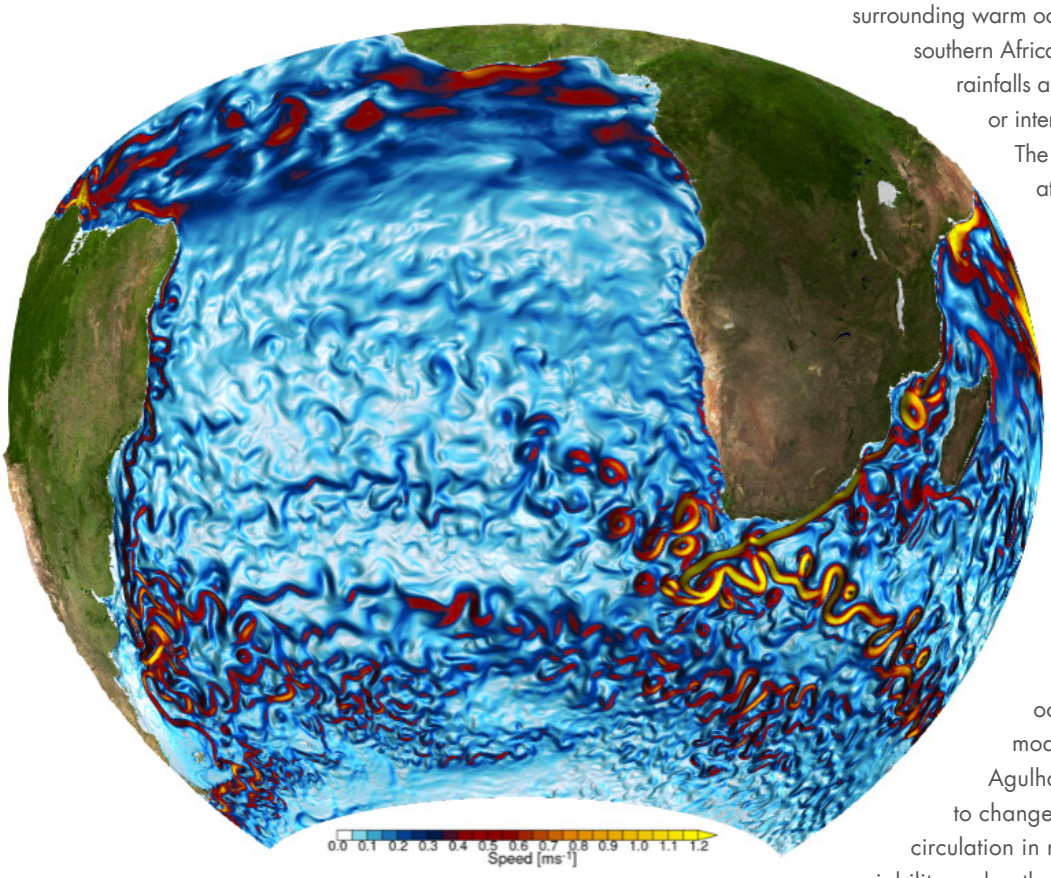
www.leibniz-zmt.de/de/forschung/wissenschaftliche-projekte/traffic.html

CASISAC – CHANGES IN THE AGULHAS SYSTEM AND ITS IMPACTS ON SOUTHERN AFRICAN COASTS

BACKGROUND

The waters around southern Africa play an important role in the world-wide system of ocean currents. They are shaped by the Agulhas Current, one of the largest currents in the world ocean, which transports warm and saline water from the tropical Indian Ocean along the African coast towards the southern tip of Africa. A part of this heat and salt reaches the South Atlantic and eventually finds its way towards the North Atlantic. There it has the potential to influence the overturning circulation and in consequence Europe's climate.

The Agulhas Current has not only a large-scale influence, but it also determines the climatic conditions around and in southern Africa. Ocean currents dynamically influence the regional sea level which is already subject to a general rise under climate change. Together with floods caused by wind waves, rising sea levels put southern Africa's coastlines under threat. In addition to this oceanic risk, there is also an atmospheric risk: The surrounding warm ocean influences rainfall in southern Africa and may cause more extreme rainfalls and different drought frequency or intensity under a warming climate. The combination of oceanic and atmos-pheric events could cause the southern African coastlines to be more vulnerable to coastal hazards in the future.



Snapshot of surface speed (in m/s) as simulated in 1/20° ocean model INALT20 (from Schwarzkopf et al., 2019, in Geoscientific Model Development).

OBJECTIVES AND RESEARCH APPROACH

In CASISAC, changes in the oceanic conditions and regional sea level around southern Africa are explored through global ocean and coupled climate modelling. The highly variable Agulhas Current System is subject to changes in the hydrography and circulation in response to atmospheric variability and anthropogenic trends. Owing to its embedding into the large-scale circulation, high-resolution ocean models of the Atlantic and Indian Ocean with grid resolutions of down to 1–5 kilometres, nested into global

Simulated compound flooding at the Breede estuary (from a compound event corresponding to 1-in-100years river discharge, waves and spring tide).

models at coarser resolution, are used. Global and regional climate models allow to research the climate response to increasing CO_2 concentrations and future recovering of the Antarctic ozone hole. A particular emphasis is on the climate extremes, such as rainfall, in southern Africa.

Sea-level changes are studied using water-level hindcasts from an ocean model and tide gauges. By combining extreme water levels that occur during storm surges with significant wave heights and increased water levels from heavy precipitation the risks and joined probabilities of compound flooding events are explored. Coastal flood impacts are assessed for South Africa at regional and local spatial scales using high-resolution hydrodynamic models of different complexity in order to accurately analyse the impacts of today's and future flood events, but also the potential benefits of different adaptation options.

STUDY AREA AND METHODS

As a strong boundary current, the Agulhas Current flows southward close along the South African coastline. After overshooting the southern tip of Africa, it follows an extra-ordinary path: Instead of flowing directly into the Atlantic Ocean, it performs an abrupt turn back into the Indian Ocean with only a minor portion, about one quarter to one third of its original volume, finding its way into the Atlantic. This happens in form of ocean eddies with horizontal diameters of several hundred kilometres and depth extensions of more than one kilometre.

In consequence, the waters southwest of southern Africa are a very variable region, called the "Cape Cauldron". Here the warm and saline Indian-Ocean water mixes with the colder and fresher South-Atlantic water, directly influencing rainfall in the western Cape around Cape Town. In contrast, rainfall in the eastern provinces is determined by the Indian Ocean. The large asymmetry in hydrographic conditions in the oceans east and west of South Africa therefore has very important consequences for regional climate and the different coastlines.

ACTIVITIES AND EXPECTED OUTCOMES

Ocean currents and hydrography are strongly shaped by eddies and fronts acting on the mesoscale (scales of the order

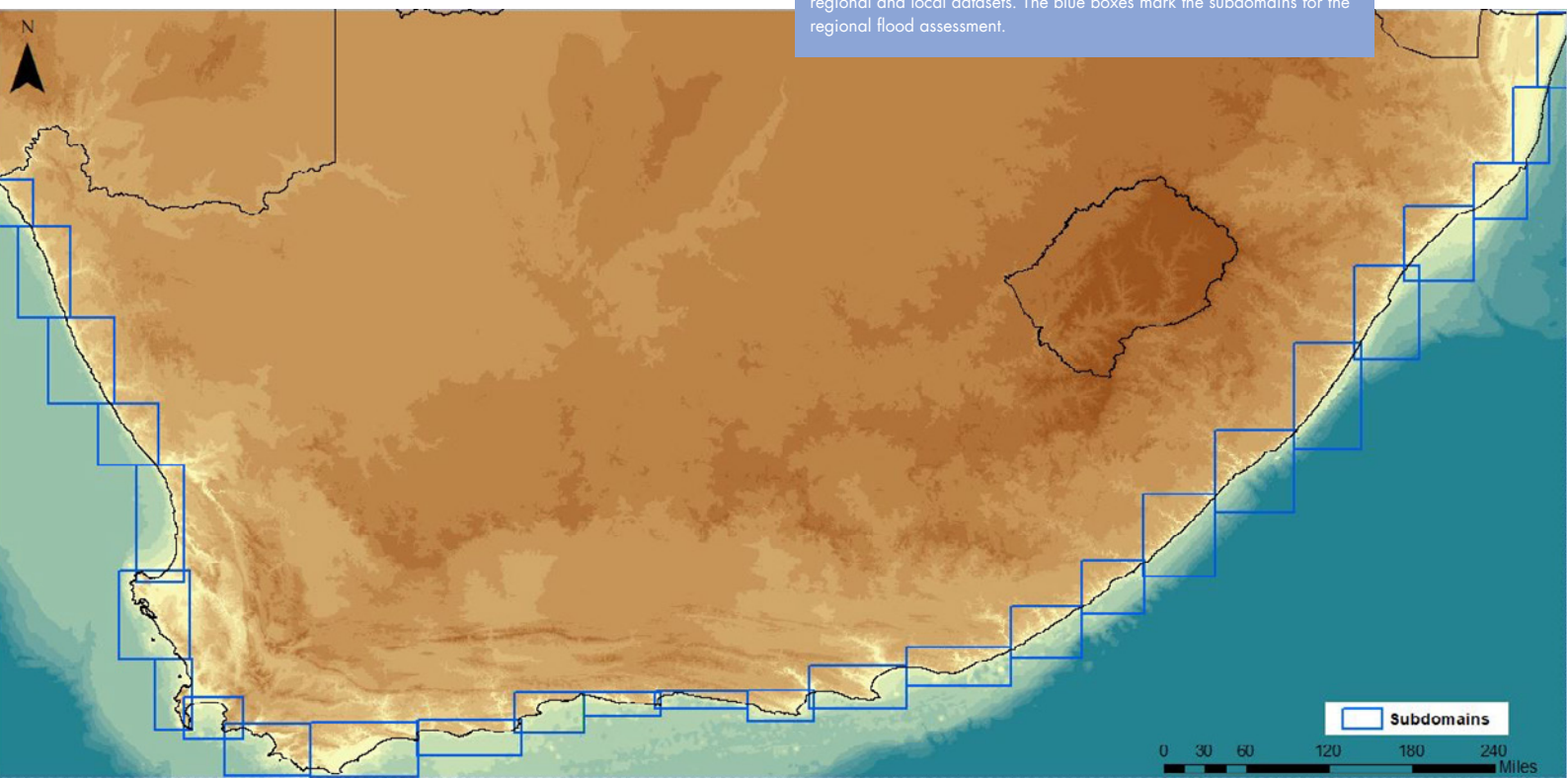
of 100 kilometres). CASISAC simulates the Agulhas Current system at high resolution to quantify the amount of heat and salt transferred from the Indian to the Atlantic Ocean, called "Agulhas leakage", and its influence on the global overturning circulation. Of particular importance for the Agulhas leakage are the westerly winds blowing south of Africa. Using ocean-atmosphere coupled climate models, CASISAC studies the impact on the westerlies by two compensating effects: the increase in anthropogenic greenhouse gases leading to an intensification of Agulhas leakage and a recovery of the ozone hole over Antarctica with an opposite effect. The impact of the ocean conditions on precipitation and droughts in southern Africa is investigated.

In the past decades, severe compound events led to critically high water levels at southern African coasts and as a consequence to property damage and loss of human life. The co-occurrence of storm surges, wind waves and flooding through heavy precipitation and runoff increases the risk of flooding and exacerbates the impacts along the vulnerable southern African coasts. To mitigate the associated high-impacts, CASISAC investigates the probability and causes of these compound events. CASISAC assesses the current and future flood impacts of the southern African coasts and accounts for different plausible socio-economic developments. Regional flood assessments performed in CASISAC allow to locate potential future hotspots where flood adaptation measurements will be required. At local or city-scales, CASISAC assesses compound flooding using detailed hydrodynamic models, which allow the analysis of interactions between flood drivers and induced effects on the resulting inundation.

PROJECT STRUCTURE AND PARTNERS

The project is structured among four national partners with the GEOMAR Helmholtz Centre for Ocean Research Kiel providing the large-scale ocean and climate modelling to research the variability of the Agulhas Current system in the past and future. Using boundary conditions from the global models, the Helmholtz-Zentrum Geesthacht GmbH (HZG) performs a regional climate model for the climate evolution in southern Africa. The Research Institute for Water and Environment at the University of Siegen (fwu) provides the joint analysis of sea level, wind waves, rainfall and runoff. These are used by the Kiel University to perform coastal flood impact assessments using hydrodynamic models for the entire South African coastline as well as for dedicated hotspots. South African partners include research bodies in Cape Town, Stellenbosch and Pretoria.

Elevation-bathymetry dataset created in CASISAC by merging global, regional and local datasets. The blue boxes mark the subdomains for the regional flood assessment.



CASISAC – CHANGES IN THE AGULHAS SYSTEM AND ITS IMPACTS ON SOUTHERN AFRICAN COASTS

COORDINATION:

GEOMAR Helmholtz Centre for Ocean Research Kiel

CONTACT:

Prof. Dr. Arne Biastoch
abiastoch@geomar.de

GEOMAR Helmholtz Centre for Ocean Research Kiel
Düsternbrooker Weg 20
24105 Kiel, Germany

PROJECT PARTNERS:

- Helmholtz-Zentrum Geesthacht GmbH (HZG)
  Geesthacht, Germany
- University of Siegen:
  Research Institute for Water and Environment (fwu)
  Siegen, Germany
- Kiel University
  Christian-Albrechts-Universität zu Kiel (CAU)
  Kiel, Germany
- University of Cape Town (UCT)
  Cape Town, South Africa
- Council for Scientific and Industrial Research (CSIR)
  Stellenbosch, South Africa
- University of Pretoria (UP)
  Pretoria, South Africa
- South African Environmental Observation Network (SAEON)
  Pretoria, South Africa

WEB PAGE:

https://casisac.geomar.de

CHANGING LANDSCAPES

TRACES – TRACING HUMAN AND CLIMATE IMPACTS IN SOUTH AFRICA

BACKGROUND

The fifth report of the Intergovernmental Panel on Climate Change (IPCC) describes southern Africa as one of the most climatically vulnerable regions in the world. The rapidly growing population and the developing industrial sector have led to a number of pressures on available ecosystem services. Contamination of air, water, soil and marine sediments has been studied at various locations in southern Africa. All results show trends of increasing threats to ecosystems, food webs and water resources. In particular, changes in precipitation in terms of its type, quantity and regional distribution have an extreme influence. In addition to climatic phenomena, other factors directly caused by humans can also be of great importance for the development of ecosystems. For example, the form of land use or industrial and agricultural pollution often plays a decisive role. Soil erosion, the over-fertilization of water bodies, the input of pollutants from mining and industry generally have a negative impact not only on biological diversity. In particular, they threaten the quality and, to some extent, the quantity of one of our most important resources – fresh water. The questions, which factors have which potential consequences and how different natural and human-induced processes influence each other, can only be answered reliably on the basis of a detailed and data-based understanding of the system. Improving the latter also in terms of a sustainable use of resources is the overarching goal of the German-South African research network TRACES.

OBJECTIVES AND RESEARCH APPROACH

The aim of the investigations in TRACES is, in addition to taking stock of current conditions, to reconstruct the respective local development history of selected ecosystems. For this purpose, a multi-parameter approach is used to analyze primarily the inorganic and organic components of sedimentary deposits. In addition, investigations on the distribution of special indicators, such as persistent organic pollutants, so-called POPs, and individual groups of organisms, which have already proven themselves in other studies as indicators for the quality status and functionality of ecosystems, are carried out. Sediment deposits of the last 250 years serve as archives with a high temporal resolution. With their help, the definition of the pre-industrial and ecological reference states will be carried out. Due to the different economic developments in the three selected study areas, we expect to be able to prove different forms, intensities and effects of anthropogenic and climatic influences. These will be made available to the local authorities and political decision makers in order to derive concrete recommendations for improved sustainable use.

E. Schefuss (right) and M. Zabel (left) filtering samples from the Mkhuze river during a sampling campaign in November 2018.

In addition to the pursuit of pure research objectives, the training of students and young scientists within a framework of capacity-development activities plays an important role within TRACES.

STUDY AREA AND METHODS

In order to answer our research questions, three research areas along the eastern part of South Africa were selected. These areas differ in recent environmental conditions, their environmental history and the extent of anthropogenic influences. As research areas were selected:1) Richards Bay with the catchments of the rivers Mhlatuze and Mfule and the Goedertrouw dam reservoir, 2) Mkhuze swamps with the river catchments of Mkhuze and Pongola and the Pongolapoort dam reservoir, 3) Olifants River catchment with the Loskop dam reservoir and two smaller reservoirs in the upstream.

On-site investigations are always performed jointly by scientists from both partner countries. Material from the listed areas, especially soil samples, sediment cores and suspension load samples, will be analyzed in the laboratories of the participating project partners. In particular, determinations of element contents, biomarkers (plant waxes), organic pollutants, stable isotopes, various parameters for age determination (for example, 14C, 137Cs), pollen and microorganisms (diatoms, ostracoda, foraminifera) are applied.

ACTIVITIES AND EXPECTED OUTCOMES

Joint fieldwork forms the basis of the activities in TRACES. This is where the samples are taken which are later examined in detail in the various national institutions, and where the first, still preliminary findings are discussed. Furthermore, the field work serves to establish direct contact or exchange with the local population and to train young colleagues. A total of at least four phases are planned in which the working areas are visited together. A very important component for knowledge transfer, training and general cooperation are also mutual research stays in the respective partner country.

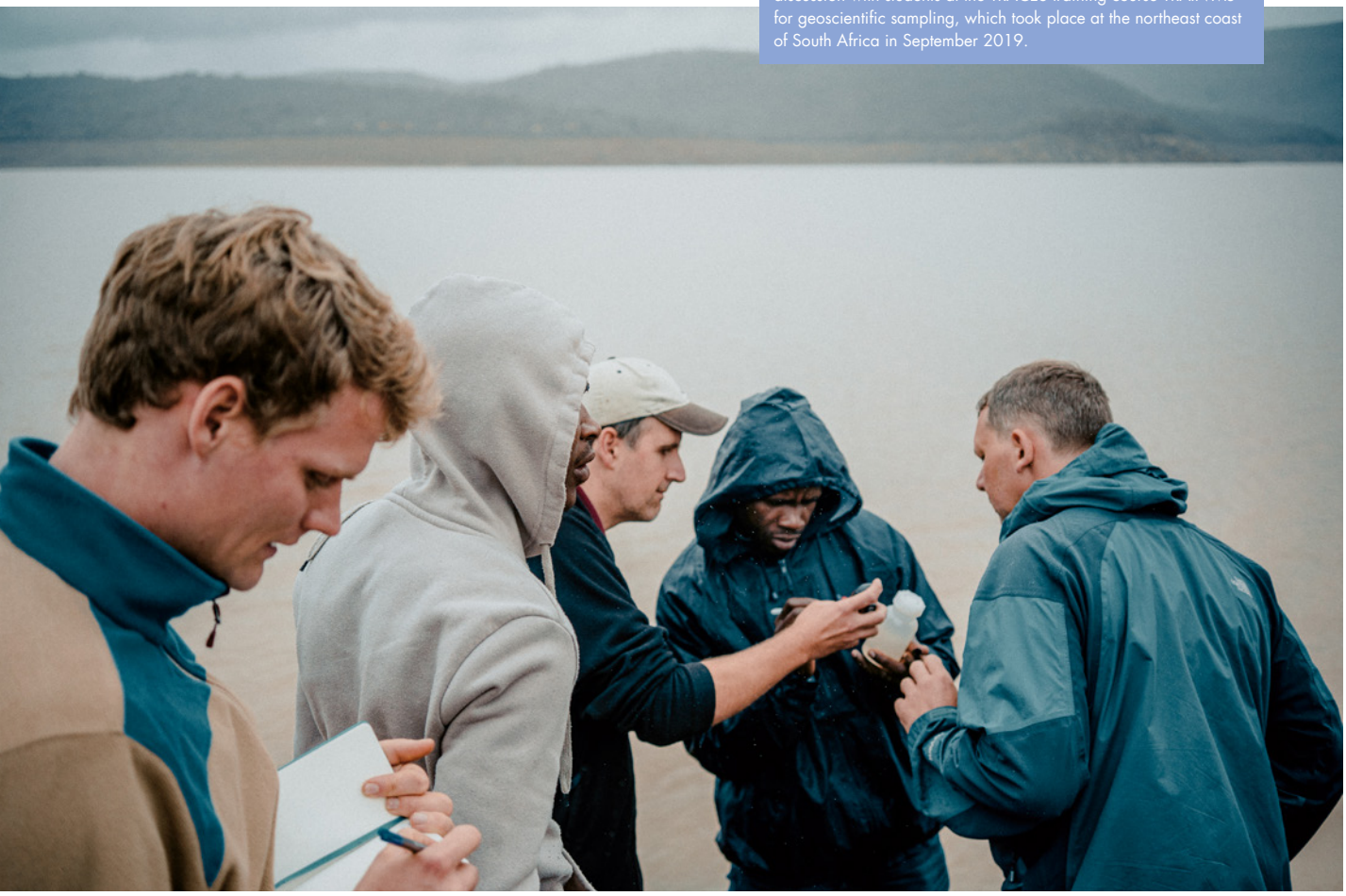
The investigations in TRACES do not pursue any immediate economic objectives. However, it is expected that the results obtained in the project on recent climate history and anthropogenic changes in the three areas under investigation will provide important new bases for environmental and economic policy decisions. In particular, this concerns the release and behavior of potential pollutants as well as the associated preservation of ecosystem functions. An important economic factor of South Africa is the "marketing" of its unique animal world. Recently increasing mass mortality, even in supposedly protected areas such as the Kruger National Park (along the Olifant River – Working Area 3), demonstrates the urgency of a more sustainable use of these important natural resources. In this respect, TRACES aims to make an important contribution to a better understanding of material cycles and the factors that determine these cycles – climate and mankind.

PROJECT STRUCTURE AND PARTNERS

TRACES is divided into five German-South African tandem sub projects that reflect the individually different scientific and analytical expertise of the partners involved. Since the

fieldwork is carried out by participants from several sub-projects, a very close linkage of the subprojects and data exchange is guaranteed. South African partners in the network are the Council for Geosciences (Dr. H. Cawthra), the University of KwaZulu Natal (Prof. A. Green, Prof. T. Hill, Dr. J Finch), the University of the Free State (Prof. L. Scott) and the University of the Witwatersrand Johannesburg (Prof. M. Humphries, Dr. F. Neumann). German partners in the network are the universities in Greifswald (Prof. T. Haberzettl, PD Dr. F. Viehberg), Jena (Prof. P. Frenzel) and Bremen (Dr. E. Schefuss, PD Dr. M. Zabel).

T. Haberzettl (centre) and F. Viehberg (right) engaged in fruitful discussion with students at the TRACES training course TRAIN-Me for geoscientific sampling, which took place at the northeast coast of South Africa in September 2019.



TRACES – TRACING HUMAN AND CLIMATE IMPACTS IN SOUTH AFRICA

COORDINATION:

University of Bremen:
MARUM – Center for Marine Environmental Sciences

CONTACT:

PD Dr. Matthias Zabel
mzabel@uni-bremen.de

MARUM – Center for Marine Environmental Sciences
University of Bremen
Leobener Str. 8
28359 Bremen, Germany

PROJECT PARTNERS:

- University of Greifswald:
  Institute for Geography and Geology,
  Department of Physical Geography
  Greifswald, Germany
- Friedrich Schiller University Jena (FSU):
  Institute of Geosciences (IGW),
  General and Historic Geology
  Jena, Germany
- Council for Geosciences (CGS)
  Pretoria, South Africa
- University of KwaZulu Natal (UKZN):
  Geography Department
  Pietermaritzburg, South Africa
- University of KwaZulu Natal (UKZN):
  Geology Department
  Durban, South Africa
- University of the Free State (UFS):
  Natural and Agricultural Sciences Faculty
  Bloemfontein, South Africa
- University of the Witwatersrand (Wits):
  Evolutionary Studies Institute
  Johannesburg, South Africa
- University of the Witwatersrand (Wits):
  Chemistry Department
  Johannesburg, South Africa

WEB PAGE:

www.marum.de/en/about-us/Sediment-Geochemistry/Traces/Project.html

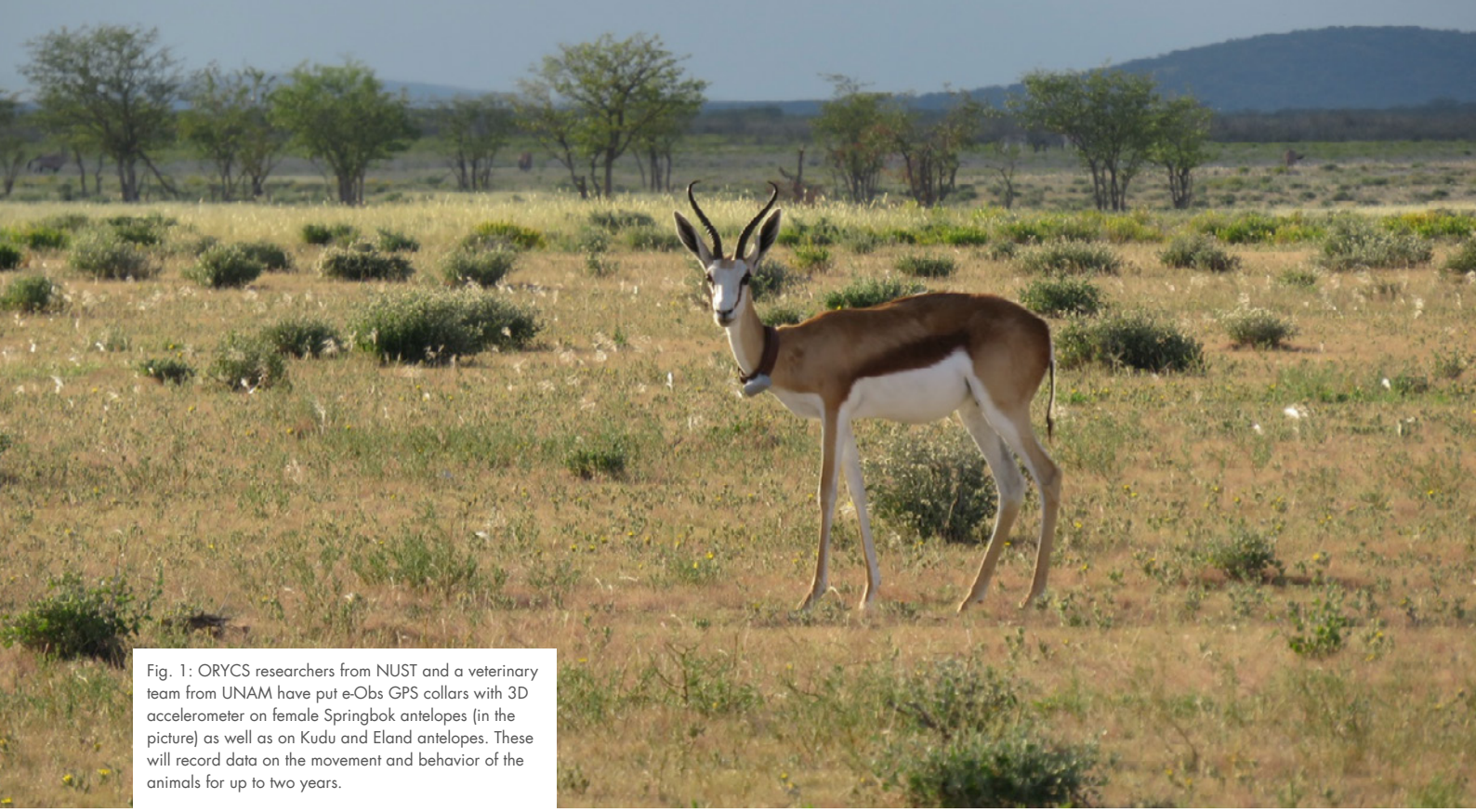


Fig. 1: ORYCS researchers from NUST and a veterinary team from UNAM have put e-Obs GPS collars with 3D accelerometer on female Springbok antelopes (in the picture) as well as on Kudu and Eland antelopes. These will record data on the movement and behavior of the animals for up to two years.

ORYCS – OPTIONS FOR SUSTAINABLE LAND USE ADAPTATIONS IN SAVANNA SYSTEMS

BACKGROUND

Changing climatic conditions and increasing land-use pressure threaten ecosystem functioning and services in savannas by altering drivers and key geo-biosphere feedbacks at the interface between soils, vegetation, wildlife and climate. In Namibia, similar to many other savannas worldwide, traditional land use based on domestic livestock has in many cases reached its limits.

One fast-growing alternative management option is a shift towards the use of native wildlife. Such wildlife-based strategies are predicated on the assumption that indigenous herbivores have higher adaptive capacities to unfavorable conditions as compared to livestock. These strategies include options based on both game-meat production and wildlife management for trophy hunting and tourism. In Namibia, already about 40 percent (not including National Parks) of the land surface is currently dedicated to wildlife-based management, including communal and freehold conservancies and private game farms.

However, despite the strong support by national policies and the rapidly increasing number of wildlife-based businesses, many examples of degraded wildlife farms already exist. To date, it remains unclear if and under what conditions wildlife-based land-use options are indeed more sustainable than traditional forms of land use under the ongoing pressures of global change.

OBJECTIVES AND RESEARCH APPROACH

Building on the successful Namibian-German collaboration in the SPACES project OPTIMASS (Options for sustainable geo-biosphere feedback management in savanna systems), ORYCS aims to evaluate the benefits but also risks of alternative wildlife-based land-use options to conserve ecosystem functions and services iNamibian savannas under current and future climatic conditions. The complex geo-biosphere feedbacks acting at the landscape scale hamper our understanding of ecosystem processes. There are major knowledge gaps on the full feedbacks between vegetation composition, condition and dynamics, animal behavior, soil processes, eco-hydrological dynamics and biodiversity. To tackle this, the interdisciplinary and integrative research approach of ORYCS combines field observations, experimental manipulations,

GPS-telemetry, remote sensing, social ecological assessments as well as modelling to analyze interactions and feedbacks between climate, water, vegetation and wildlife for different types of wildlife-based land-use options.

Centered around an understanding of spatial and temporal patterns of habitat and resource use by key endemic antelope species, ORYCS is assessing the impact of wildlife management on key ecosystem services like water provision, forage and food production, biodiversity and tourism, but also looking into human-wildlife conflicts arising around those types of land use. ORYCS will provide a first scientific basis for optimizing innovative strategies that are critically needed for sustainable wildlife-based land-use management options in diversely used savanna landscapes.

STUDY AREA AND METHODS

Research will focus on the semi-arid Mopane savanna south-west of and including the western part of Etosha National Park, Namibia. Land use types present in the area are representative for the Namibian wildlife sector and comprise national park, communal conservancy and commercial farmland all featuring various compositions of livestock and wildlife. In this area we find an excellent framework to integrate existing hydrological, ecological and socio-ecological data with the planned research. Importantly, the Ehi-Rovipuka communal conservancy within the study area is amongst the earliest conservancies established in Namibia, meaning geo-biosphere conditions have had time to change. Our permanent field station is located at the 47.000 hectare sized private game reserve "Etosha Heights".

In close dialogue with stakeholders, ORYCS will apply a combination of animal-movement studies, vegetation surveys, eco-physiological and hydrological measurements and experiments, remote sening, socio-ecological assessments and different process-based computer models to close the abovementioned knowledge gaps. Our intense science-stakeholder dialogue (Fig. 2) and particularly the partnership with the Ministry of Environment, Forestry and Tourism (MEFT) allows the ORYCS research to be relevant for policy and management.

Fig. 2: ORYCS team with stakeholders from farms, conservancies , national-park administration and other institutions during stakeholder workshop in Outjo, Namibia in April 2019.

ACTIVITIES AND EXPECTED OUTCOMES

ORYCS research is based upon a profound understanding of large herbivores, movement in the savanna landscape. Therefore, ORYCS deploys GPS collars with 3D-accelerometers (Fig. 1) on different key wildlife species. Combined with data from MEFT (for example, on movement and densities of elephant, giraffe, kudu, eland, springbok) this information is used to understand resource and space use of wildlife over time. Additionally, the effects of wildlife on the ecosystem will be assessed by fusing field measurements on biodiversity across taxa, soil characteristics, vegetation structure and groundwater with highly resolved data from airborne and satellite sensors, with experimental and observational eco-physiological data (for example, Fig. 3) and with social-ecological information from interviews and surveys on management frame conditions, strategies and human-wildlife conflicts. Different process-based simulation models will integrate the information to predict vegetation dynamics and composition, animal spaces use and functional composition of wildlife communities for various scenarios of climate and land use.

The interdisciplinary approach will result in comprehensive information leading to fundamental insights into the Mopane-savanna ecosystem and the ecology of large herbivores, the water fluxes in this ecosystem, but also into applied questions like ecological and economic sustainable strategies for wildlife-based land use and biodiversity conservation, for example. In a continuous effort, ORYCS assures transdisciplinary cooperation with the Namibian Ministry of Environment, Forestry and Tourism, the Etosha National Park, with local farmers and conservancy representatives. In this way, results can be generated that are easily applicable to land users and decision makers.

Fig. 3: Different sensor systems are installed in the field. (A) Continuous sap-flow measurements are used to understand how water fluxes through woody plants are affected by different simulated browsing scenarios. Browsing is experimentally simulated by clipping leaves of single branches or whole trees at different ratios. (B) Logger systems store the continuous information alongside with additional data on climate, soil moisture, solar radiation and other environmental parameters.

To also achieve academic sustainability, ORYCS includes a profound education and exchange component and fair data sharing and publication protocols. Embedded in the SPACES II training and the SPACES II DAAD programmes, ORYCS will facilitate the exchange of students between southern Africa and Germany as well as their education by means of training courses and jointly supervised thesis projects. Exchange is further supported by the ORYCS tandem programme where a student from Namibia teams up with a student from Germany to jointly conduct their theses on complementary subjects.

PROJECT STRUCTURE AND PARTNERS

ORYCS is a German-Namibian cooperation of three Namibian and three German institutions (Fig. 4). The project is coordinated by the University of Potsdam together with the NUST Biodiversity Research Centre in Windhoek, Namibia. Further partners are the Freie Universität Berlin, the Institute for Social-Ecological Research (ISOE), the University of Namibia and the Namibian Ministry of Environment, Forestry and Tourism (MEFT).

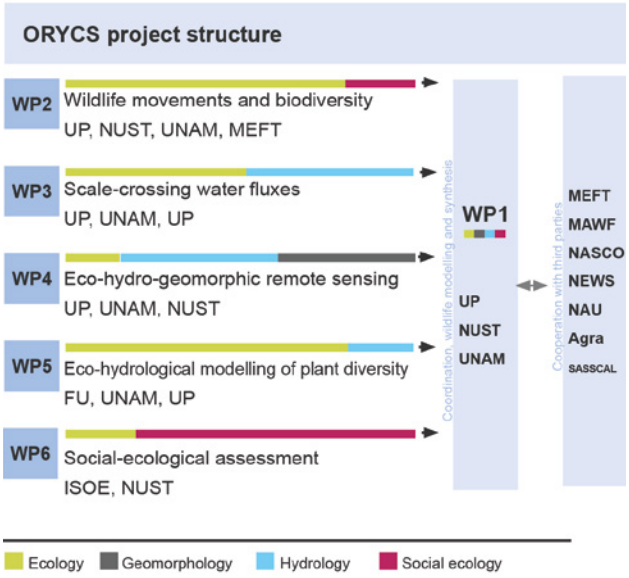


Fig. 4: Project structure and cooperation partners (UP: University of Potsdam; NUST: Namibia University of Science and Technology: UNAM: University of Namibia; FU: Freie Universität Berlin; ISOE: Institute for Social-Ecological Research; MET: Namibian Ministry of Environment and Tourism; MAWF Namibian Ministry of Agriculture, Water & Forestry; NEWS: Namibian Environment and Wildlife Society; NACSO: Namibian Association of Community Based Natural Resources Management Support Organizations; NAU Namibia Agricultural Union; NAPHA: Namibia Professional Hunting Association).

ORYCS – OPTIONS FOR SUSTAINABLE LAND USE ADAPTATIONS IN SAVANNA SYSTEMS

COORDINATION:

University of Potsdam:
Plant Ecology and Nature Conservation

CONTACT:

PD Dr. Niels Blaum
blaum@uni-potsdam.de

University of Potsdam,
Plant Ecology and Nature Conservation
Am Mühlenberg 3
14467 Potsdam, Germany

PROJECT PARTNERS:

- Freie Universität Berlin
  Berlin, Germany
- Institute for Social-Ecological Research (ISOE)
  Frankfurt am Main, Germany
- Namibia University of Science and Technology (NUST):
  Biodiversity Research Center
  Windhoek, Namibia
- University of Namibia (UNAM)
  Windhoek, Namibia
- Namibian Ministry of Environment,
  Forestry and Tourism (MEFT)
  Windhoek, Namibia

WEB PAGE:

www.orycs.org

Cattle on rangeland with high grazing pressure at the end of the dry season in October 2019.

SALLNET – SOUTH AFRICAN LIMPOPO LANDSCAPES NETWORK

BACKGROUND

Rangelands, arable lands and tree orchards are very common land-use types in southern Africa. In their specific spatial arrangements, they constitute multifunctional landscapes that provide essential ecosystem services, for example, food production, biodiversity, pollination and carbon sequestration. Many of the ecosystem services provided by these landscapes are crucial for supporting local livelihoods, protecting biodiversity and a wide range of other Sustainable Development Goals (SDGs) of the UN, in particular: no poverty, zero hunger, good health, clean water, climate protection and sustainable land-use. Yet, through continued strong population increases and accelerated climate change with more frequent and severe adverse climate extremes such as droughts, the already fragile savannah ecosystems in southern Africa and the multiple services they provide are increasingly threatened.

Therefore, SALLnet focuses on how to enhance the resilience of multifunctional landscapes in southern Africa under the conditions of climate change, growing population and increased resource limitations.

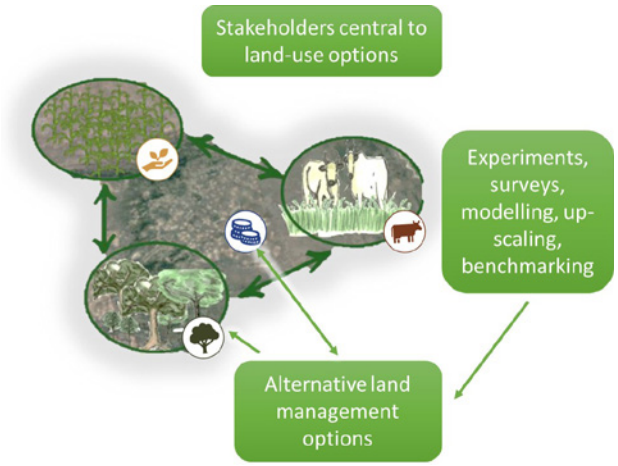
OBJECTIVES AND RESEARCH APPROACH

The main objective of SALLnet is to answer the overarching question: How can the resilience of the multifunctional landscapes in South Africa's Limpopo region be enhanced under future climate conditions?

SALLnet considers climate variability and change as the main sources of risk, but approaches them as a multiplier of existing socio-economic risks and is therefore paying due attention to other drivers of land-use change such as urbanisation processes.

Aiming to enhance the resilience of land use, ecosystem services and landscapes, to anticipate changes in climate and socio-economic drivers, SALLnet designs an inter- and transdisciplinary framework to develop and evaluate alternative land-use management scenarios at multiple scales. To do so, SALLnet identifies, selects and investigates a set of different possible land-use management scenario options paying special attention to link these scenarios to the Sustainable Development Goals and local policy objectives. Assessing the effectiveness of management options is key to

enhance the resilience of different land-use systems and to reduce risks to ecosystem services.



SALLnet's systems approach to analyse interactions among different land-use types and their multifunctionality under current and future conditions.

STUDY AREA AND METHODS

SALLnet focuses on the province of Limpopo as its case-study area because of the diverse land use, biodiversity and high spatiotemporal climatic variability of this region. Due to these characteristics, the region is particularly appealing to generalise the findings and make recommendations for similar managed ecosystems in southern Africa. SALLnet is developing and testing new approaches and methods for more sustainable land use, with a focus on the interactions between the connected land-use types: arable lands, rangelands and tree orchards.

ACTIVITIES AND EXPECTED OUTCOMES

SALLnet focuses on the management of the three major land-use types within Limpopo's multifunctional landscapes in the given socio-economic context – arable lands, rangelands, and tree orchards – and connects these land-use types in an integrated analysis. To analyse sustainable land-use options, SALLnet carries out experimentations and surveys. Generated data will be used to develop integrative tools and modelling platforms for an overall risk evaluation and to develop alternative land-use scenarios and management options to enhance the ecosystems' resilience. The modelling results will be scaled up to various decision levels (farm, province).

The scenarios will be developed in close interaction with local stakeholders, who are involved in the entire research process, and they will be evaluated and compared with respect to a set of pre-defined sustainability indicators (ecological, economic and social). They will build on issues that have emerged in previous or ongoing science-policy dialogues in/about the Limpopo region.

This eventually will result in a synthesis for the land-use types, their interactions and policy implications to generate alternative land-use strategies, to protect the functionality and resilience of multifunctional landscapes in southern Africa and to enhance food security.

Arable ground-truthing survey of small-scale farmer systems (predominantly maize), April and May 2019. Extremely poor maize yields were recorded in one of the driest and hottest regions surveyed (Selwane, Limpopo province).

PROJECT STRUCTURE AND PARTNERS

In SALLnet, research is carried out in four subprojects focusing on the specific land-use types and the modelling and scenario development. Within these subprojects, six German institutions at the University of Goettingen, the Senckenberg Society for Natural Research and the University of Bonn cooperate with five South African partner institutions at the Universities of Limpopo, the Witwatersrand and Venda. To meet the goals of the project, researchers from different disciplines such as agroecology, agronomy, soil science, agricultural economics, and agricultural systems modelling are contributing.

Taking soil samples in macadamia orchards at Neuhof farm, fall 2019.

In discussion with farmers: small-scale farmer survey, spring 2019.

SALLNET – SOUTH AFRICAN LIMPOPO LANDSCAPES NETWORK

COORDINATION:

University of Goettingen:
Tropical Plant Production and Agricultural Systems Modelling (TROPAGS)

CONTACT:

Prof. Dr. Reimund P. Rötter
rroette@gwdg.de

Tropical Plant Production and Agricultural Systems Modelling (TROPAGS)
University of Goettingen
Grisebachstraße 6
37077 Göttingen, Germany

PROJECT PARTNERS:

- University of Goettingen:
  Agricultural Economics and Rural Development, Functional Agrobiodiversity, Grassland Science
  Göttingen, Germany
- Senckenberg Society for Natural Research:
  Biodiversity and Climate Research Centre (SBiK-F)
  Frankfurt am Main, Germany
- University of Bonn:
  Institute of Crop Science and Resource Conservation (INRES)
  Bonn, Germany
- University of Limpopo (UL):
  Risk and Vulnerability Assessment Centre
  Sovenga, South Africa
- University of Venda (UNIVEN):
  School of Mathematical and Natural Sciences, Department of Soil Sciences
  Thohoyandou, South Africa
- University of Witwatersrand (Wits):
  School of Animal, Plant and Environmental Science, The Global Change Institute
  Johannesburg, South Africa

WEB PAGE:

www.uni-goettingen.de/en/592566.html

EMSAFRICA – ECOSYSTEM MANAGEMENT SUPPORT FOR CLIMATE CHANGE IN SOUTHERN AFRICA

BACKGROUND

Along with increasing temperatures, the projected impacts of climate change in southern African terrestrial ecosystems include altered patterns of rainfall and fire as well as increased frequency of extreme weather events. Higher levels of carbon dioxide in the atmosphere affect the interactions between plant groups. At the same time, terrestrial ecosystems are affected by human activities, such as livestock grazing, cultivation, fuelwood extraction and the spreading of invasive alien species.

Climate change and human management affect the distribution of plants, leading to shifts and alterations of entire biomes. The dynamics and functioning of ecosystems are also projected to change, altering their ability to sequester carbon from the atmosphere.

The complexity and interdependence of climate-management interactions make the ecosystem responses difficult to predict. The current understanding of the feedbacks between key savanna-ecosystem responses to, for example, fire dynamics and grazing is insufficient. Due to lack of long-term experiments particularly in managed ecosystems, the role of Africa in the global carbon dynamics remains poorly known.

OBJECTIVES AND RESEARCH APPROACH

EMSAfrica introduces a multidisciplinary approach where various experiments, surveys and measurements, conducted under a carefully designed field setup, feed into a variety of models at multiple scales.

Eddy-covariance flux tower at the EMSAfrica Middelburg site, Eastern Karoo.

The project has four broad aims:

- establish infrastructure and modelling tools to estimate the carbon balance of main South African terrestrial ecosystems
- assess the potential impacts of climate change on biodiversity and ecosystems in South Africa
- provide information to support sustainable land-use and climate-relevant decision making via multiple levels of stakeholder interaction
- develop capacities via researcher exchange and degree grants and implement summer schools and workshops, in particular to enable future sustainable use of the project research infrastructures

STUDY AREA AND METHODS

The EMSAfrica field setup is designed to distinguish between land-use and climate-induced impacts on ecosystem structure and function. Three focal research areas are located along a precipitation gradient, from low to high precipitation. In each area, paired observation sites represent different intensities of land use – for example, a protected ecosystem compared with livestock grazing or a peri-urban landscape.

On each site, an eddy-covariance flux tower measures the land-atmosphere exchange of carbon dioxide and water vapour. Plant ecophysiological traits are investigated with field measurements and the responses of different plant growth forms to climate change are studied with phytometer experiments. Earth-observation approaches are used to characterise the spatial dynamics of vegetation structure. On some sites, socio-economic surveys are conducted to study human use of ecosystems.

The various data, supplemented with pre-existing national datasets, are used to create, calibrate and test vegetation and ecosystem models as well as to scale them up to make predictions on the impacts of climate change at the biome level.

ACTIVITIES AND EXPECTED OUTCOMES

Continuous land-atmosphere measurements of the fluxes of carbon dioxide and water help us to assess which factors affect primary production under different management regimes. Photosynthesis and soil respiration measurements support the analysis of carbon fluxes. In combination with other data and models, these measurements help to improve the estimations of the overall carbon balance of southern African ecosystems.

To assess the changes in species ranges and biome shifts, EMSAfrica conducts field monitoring and species distribution modelling. Biome shift monitoring phytometers (BISMOPs) are small garden experiments where different plant growth forms, each characteristic of a specific biome, are planted in different climatic regions and their physiological activity is monitored.

Projections of vegetation changes under different scenarios of climate change and land use are produced using Dynamic Vegetation Models (DVMs). DVMs are computer-based models used to simulate the growth and distribution of plants in response to drivers such as fire, climate or grazing as well as the interactions between them.

Fig. 1: Use of unmanned Aerial Vehicles (UAV) at Middelburg site in Eastern Cape (left) and UAV products for the Agincourt site, Bushbuckridge (right).

To support all analyses and models, we collect multi-temporal remote sensing and ancillary geospatial data from various platforms and sensing schemes on each project site. In addition, novel earth-observation and analysis methods are developed to monitor and map South African ecosystems.

Socio-ecological survey data is collected to support analyses on for example, the role of humans as fuelwood collectors. This data parametrized an agent-based model (ABM) to mimic firewood collectors' adaptive behaviour responding to population growth and climate change.

Fig. 2: Biome shift monitoring phytometer (BISMOP) construction.

To create climate-relevant support for ecosystem management, EMSAfrica researchers work with two local land-user groups to provide solutions to locally defined challenges. In addition, a large-scale multi-agent modelling and simulation framework is used to develop management solutions for national parks authorities (SANParks).

EMSAfrica runs training workshops in South Africa and is involved in activities to engage policy stakeholders into project steering and the use of project outcomes. Special emphasis is placed on collaboratively building technical capacity to transfer project infrastructures as part of South African environmental observation networks at the end of the project.

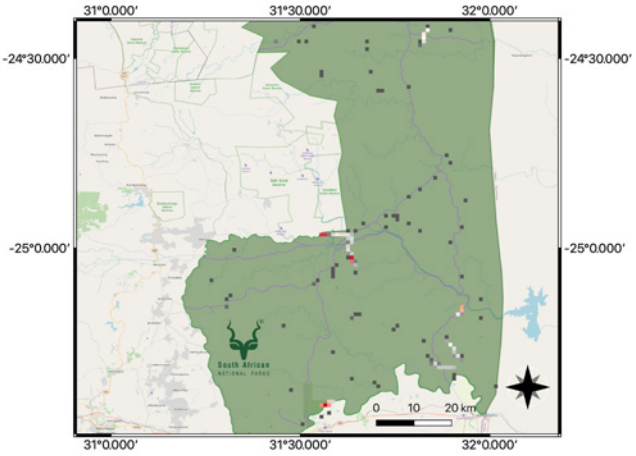


Fig. 3: Tourist-car density (red = high) in the southern part of the Kruger National Park (simulated).

PROJECT STRUCTURE AND PARTNERS

EMSAfrica is a collaborative project between South African universities (Stellenbosch University, University of the Witwatersrand, University of Venda, Rhodes University) and research institutes (Council for Scientific and Industrial Research CSIR, South African Environmental Observation Network SAEON, Grootfontein Agricultural Development Institute GADI, Southern African National Parks SANParks), the Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL) as well as German Universities (University of Bayreuth, Goethe University Frankfurt, Friedrich Schiller University Jena, Hamburg University of Applied Sciences) and research institutes (Thünen Institute, Senckenberg Institute).

EMSAFRICA – ECOSYSTEM MANAGEMENT SUPPORT FOR CLIMATE CHANGE IN SOUTHERN AFRICA

COORDINATION:

University of Bayreuth

Johann Heinrich von Thünen Institute:
Institute of Climate-Smart Agriculture (TI-AK)

CONTACT:

Prof. Dr. Steven Higgins
steven.higgins@uni-bayreuth.de

University of Bayreuth
Universitätsstr. 30
95447 Bayreuth, Germany

Dr. Mari Bieri
mari.bieri@thuenen.de

Thuenen Institute of Climate-Smart Agriculture
Bundesallee 68
38116 Braunschweig, Germany

PROJECT PARTNERS:

- Goethe University Frankfurt
  Frankfurt am Main, Germany
- Friedrich Schiller University Jena (FSU)
  Jena, Germany
- Hamburg University of Applied Sciences
  Hamburg, Germany
- Senckenberg Society for Natural Research:
  Biodiversity and Climate Research Centre (SBiK-F)
  Frankfurt am Main, Germany
- Stellenbosch University (SU)
  Stellenbosch, South Africa
- University of the Witwatersrand (Wits)
  Johannesburg, South Africa
- University of Venda (Univen)
  Thohoyandou, South Africa
- Rhodes University (RU)
  Grahamstown, South Africa
- Council for Scientific and Industrial Research (CSIR)
  Pretoria, South Africa
- South African Environmental Observation Network (SAEON)
  Pretoria, South Africa
- Grootfontein Agricultural Development Institute (GADI)
  Middelburg, South Africa
- South African National Parks (SANParks)
  Pretoria, South Africa
- Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)
  Windhoek, Namibia

WEB PAGE:

www.emsafrica.org

TWITTER:

@EMSAfrica

Vines and windbreaks in South Africa.

ASAP – AGROFORESTRY IN SOUTHERN AFRICA: NEW PATHWAYS OF INNOVATIVE LAND-USE SYSTEMS UNDER A CHANGING CLIMATE

BACKGROUND

New and innovative land-use solutions are needed to adapt to a rapidly changing climate and to mitigate the predicted impacts on rural livelihoods. Projected effects caused by climate change are suggested to severely impact southern Africa. These may occur as an increase in drought and flooding events and shifts in rainfall patterns resulting in a reduction of production potential and a loss of productive cropland, thus negatively affecting economic, ecological and social aspects of sustainable development.

Agroforestry systems (AFS) present the potential to preserve natural resources and biodiversity against climate-change influences, to improve the bio-economy in rural areas and to provide an adaptation strategy for human needs. The research project "Agroforestry in Southern Africa – new pathways of innovative land use systems under a changing climate", (ASAP) targets the application of agroforestry systems as a suitable response to the impacts of climate change and to supplement awareness of the requirements of stakeholders, land managers and subsistence farmers in respect to the agricultural land they utilise and the potential pressures they are exposed to, due to climate change.

In southern Africa, agroforestry-based land-use strategies have great potential to contribute effectively to several relevant Sustainable Development Goals (SDGs), including poverty eradication, food security and biodiversity conservation.

OBJECTIVES AND RESEARCH APPROACH

In an inter- and transdisciplinary approach the ASAP project aims to both develop and cement knowledge concerning agroforestry systems in southern Africa utilising simple and replicable methodology as well as applying innovative technological solutions across the entire study region at the farm, landscape and national scales. The three main goals of the ASAP project are:

› The investigation of ecosystem services and environmental benefits of agroforestry systems as an innovative, multi-purpose land-use management practice in southern Africa:

The project will study the effects of the utilisation of trees within a farmed landscape in terms of soil mechanical processes, hydrological fluxes and flows, nutrient cycles, light regime as well as an assessment of the carbon sequestration potential.

› An exploration of human-environment interactions within AFS and their benefits for rural livelihoods and local stakeholders: The project will also assess the social, political and economic contexts guiding the establishment of agroforestry policies at national level and the effects or implications of utilising trees within agricultural land in order to guide regional policy makers.

› A development of German – southern African research cooperation and capacity building with the bi-directional transfer of knowledge and educational transmission, providing multiple opportunities for exchange and collaboration at multiple levels.

STUDY AREA AND METHODS

The ASAP project aims to study complementary and contrasting areas in southern Africa with a focus on existing agroforestry systems employed within them. Comparisons and disparities as well as synergies between differing agroforestry systems are analysed especially in terms of interactions between trees and crops influencing the surrounding bio-physical environment. Project partners in South Africa, Mozambique, Namibia, Zambia and Malawi are ideally located to collaborate with teams in Germany in research and dissemination tasks with outreach and the sharing of knowledge for a mutual benefit and for stakeholders in the study regions.

ACTIVITIES AND EXPECTED OUTCOMES

The trees and crops, soils, water regime and microclimates are studied within selected agroforestry systems and the interactions that occur between the different elements are analysed by experts in their field translating to a truly multi-disciplinary research approach. The project will identify and study some of the most appropriate tree species for defined agroforestry applications within southern Africa and will facilitate the dissemination of guidelines for the management of such systems. This will require the compilation and advancement of understanding of individual tree species within the southern African research area utilising traditional knowledge, established scientific methodology and combining it with innovative technical solutions (such as terrestrial laser scanning, drone-based surveys and photographical analysis). Experimental design and applied scientific methodology across all disciplines are intended to be straightforward to establish and undertake in order to facilitate replicability across the study range by multiple partners, thus ensuring high-resolution data capture and achieving a maximum collaboration potential across the study region.

The project undertakes an examination of the positive and negative effects of the utilisation of trees within a farmed landscape. Detailed measurements, analyses and modelling activities will be undertaken within multi-disciplinary fields including soil mechanical processes, hydrological fluxes and flows, nutrient cycles, shading, an assessment of the carbon sequestration potential as well as ecophysiological measurements. Such work will allow researchers and land managers to target future research where it is needed. Likewise, ASAP targets an understanding of the social demands and impacts that agroforestry systems can offer. The project will foster an understanding of the social demands and impacts that AFS can bring to the study region. This will aid regional policy makers in evaluating future support for such innovative land use systems.

PROJECT STRUCTURE AND PARTNERS

Combining multiple partners, the project presents a multi-national, multi- and transdisciplinary collaboration. The project is lead and coordinated by the Chair of Forest Growth and Dendroecology, University of Freiburg in Germany, and complemented by the Chairs of Soil Ecology as well as Forest and Environmental Policy at the same university. Teams from the Institute of River Basin Management from the Karlsruhe Institute of Technology (KIT), the Centre for Energy Technology Brandenburg (CEBra) and from the Working group Landscape Pedology located within the Leibniz Centre for Agricultural

Fig. 1: Installing water sensors under agroforestry trees.

Landscape Research (ZALF) are central within the project's implementation. These research groups collaborate with the Department of Forest and Wood Science, Stellenbosch University, South Africa; the Faculty of Natural and Agricultural Sciences, University of Pretoria, South Africa; Department of Forestry, Eduardo Mondlane University, Mozambique; Department of Plant and Enviromental Sciences, The Copperbelt University, Zambia; Economic Botany Programme, National Botanical Research Institute, Namibia; World Agroforestry (ICRAF, Southern African Node, Malawi) and SASSCAL, the Southern African Science Service Centre for Climate Change and Adaptive Land Management located in Namibia.

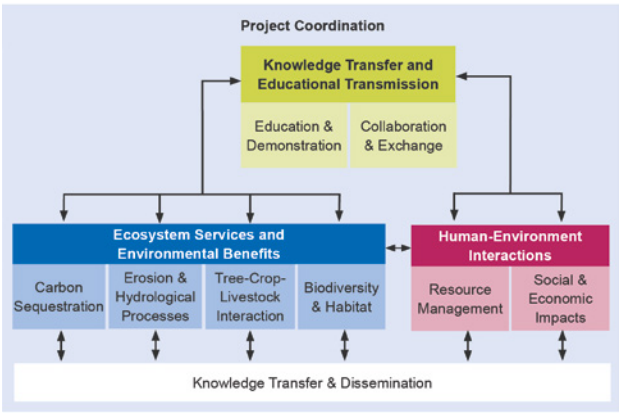


Fig. 2: ASAP project working-package structure showing interlinkages between research activities and dissemination.

ASAP – AGROFORESTRY IN SOUTHERN AFRICA: NEW PATHWAYS OF INNOVATIVE LAND-USE SYSTEMS UNDER A CHANGING CLIMATE

COORDINATION:

University of Freiburg:
Faculty of Environment and Natural Resources,
Chair of Forest Growth and Dendroecology

CONTACT:

Prof. Dr. Hans-Peter Kahle
hans-peter.kahle@iww.uni-freiburg.de

Dr. Jonathan Sheppard
jonathan.sheppard@iww.uni-freiburg.de

asap@agroforestry-africa.org

PROJECT PARTNERS:

- Karlsruhe Institute of Technology (KIT)
  Karlsruhe, Germany
- Leibniz Centre for Agricultural Landscape Research (ZALF)
  Müncheberg, Germany
- Centre for Energy Technology Brandenburg (CEBra)
  Brandenburg, Germany
- Stellenbosch University
  Stellenbosch, South Africa
- University of Pretoria (UP)
  Pretoria, South Africa
- National Botanical Research Institute (NBRI)
  Windhoek, Namibia
- Eduardo Mondlane University (UEM)
  Maputo, Mozambique
- The Copperbelt University (CBU)
  Kitwe, Zambia
- World Agroforestry (ICRAF):
  Southern Africa Node
  Lilongwe, Malawi
- Southern African Science Service Centre for Climate Change and Adaptive Land Management (SASSCAL)
  Windhoek, Namibia

WEB PAGE:

www.agroforestry-africa.org

SALDI – SOUTH AFRICA LAND DEGRADATION MONITOR

BACKGROUND

Land degradation deteriorates ecosystem functioning and services including soil fertility as well as biological productivity and is accompanied by a loss of biodiversity. In semi-arid and arid regions, this process is reinforced by climatic fluctuations on the decadal scale, resulting in prolonged drought and crop losses, for example. Predicted future climate change and socio-economic challenges worsen the situation and call for a precise identification of areas affected by land degradation in order to allocate means to combat land degradation more effectively.

Recent developments in the fields of remote sensing and modelling of land-surface processes as well as land-surface-atmosphere interactions provide the opportunity to identify the underlying subtle processes of land degradation with unprecedented spatial resolution and precision. It is now possible to instantaneously monitor land-surface change bi-weekly and in a spatial resolution that provides meaningful insight, even on the "back-yard scale" of 10 metres.

OBJECTIVES AND RESEARCH APPROACH

Taking advantage of recent technical and methodological developments, it is the aim of SALDi

- to develop an automated system for high temporal frequency (bi-weekly) and high spatial resolution (10 to 30 metres) monitoring of land-surface and of ecosystem-service dynamics,
- to adapt and apply a numerical Regional Earth System Model (RESM) to South Africa and investigate feedbacks between land-surface properties and regional climate,
- to advance current soil-degradation process-assessment tools for soil erosion.

Protected areas within our study regions represent benchmark sites, providing a foundation for baseline trend scenarios, against which climate-driven ecosystem-service dynamics of multi-used landscapes (cropland, rangeland, forests) will be evaluated. To make sure that the developed tools will be applicable across different stakeholder levels, the socio-economic dimension of land degradation and a validation of the usefulness of the monitoring products to local farmers is an important objective of the investigations.

Fig. 1: Assessing soil hydraulic properties and erodibility of a heavily utilized area using a rainfall simulator in the southern Kruger National Park, Mpumalanga, South Africa.

STUDY AREA AND METHODS

SALDi focusses on six study sites representing a major climate gradient from the semi-arid winter-rainfall region in the south-west across the central semi-arid year-round-rainfall region to the semi-humid summer-rainfall region in the northeast. The sites also cover different geological conditions and different agricultural practices. These include commercial, rain-fed and irrigated cropland, free-range cattle and sheep farming as well as communal and subsistence farming. Thus, the sites basically represent the climatological, ecological, socio-economic and cultural diversity of/in South Africa. Furthermore, sites were selected to consider the incisive biome changes expected under the predicted global climate change.

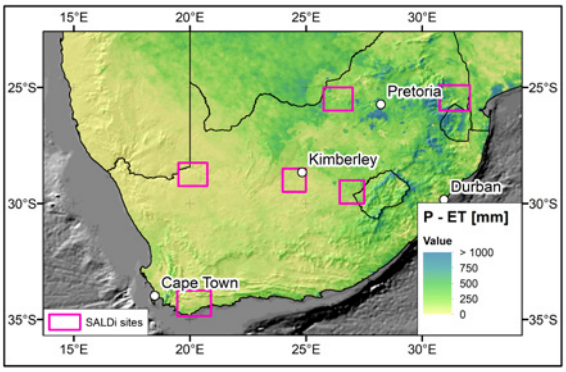


Fig. 2: SALDi study sites in South Africa and modelled water balance (precipitation (P) - evaporation (ET)) for the year 2010 highlighting the strong underlying climatic gradient across the country providing the framework for land-degradation processes.

ACTIVITIES AND EXPECTED OUTCOMES

The SALDi activities during the first half of the project life time included field-survey campaigns to assess soil properties and erosion (Fig. 1) and land surface dynamics (Fig. 3), the development of algorithms for the synergistic exploitation of the generated Sentinel-1 and Sentinel-2 remote-sensing data cube as well as the setup of the Regional Earth System Model (RESM) (WRF-Hydro®, Weather Research and Forecasting Model Hydrological modeling system) for the weather and climate modelling. First results of the latter, providing the water balance for the year 2010, were used to highlight the climatic gradient in the SALDi study site map (Fig. 2). According to this, the water balance in the year 2010 for our study sites varied from about 10 millimetres at Kai !Garib in the northwest to 400 millimetres in Ehlanzeni, Mpumalanga in the northeast.

Another example for first results is provided by the two remote-sensing groups working on synergistic land-surface change detection based on the optical and radar Sentinel satellites of the European Space Agency (ESA). By combining different acquisitions, the Sentinel-1 radar backscatter (Fig. 3, left) can be used to draw conclusions about cultivation dynamics (for example, ripening processes) in agricultural areas (pivot irrigation) as well as the surrounding grasslands. The figure shows this as an RGB composite where each color represents the backscatter intensity of one acquisition.

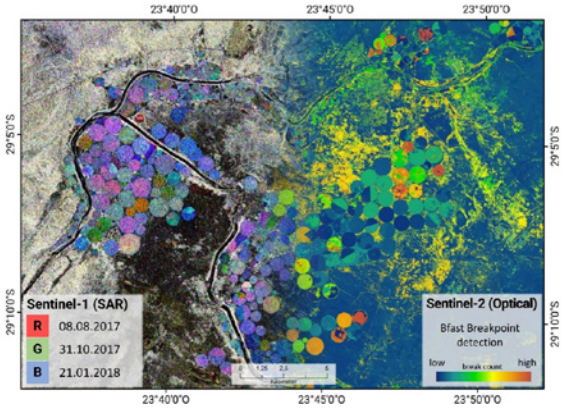


Fig. 3: Synergistic combination of Sentinel-1 radar (left) and Sentinel-2 optical (right) time series to monitor land-surface dynamics (for example, pivot irrigation and grasslands) near Douglas, Northern Cape Province, west of Kimberley. The figure contains modified Copernicus Sentinel data [2015–2020].

In detail, magenta areas represent high backscatter (due to volume scattering from the crops) in August 2017 and January 2018, whereas blue regions on the left have higher backscatter in January 2018, only which allows interpretation of the growing cycles of the pivot irrigation areas. On the right, Fig. 3 presents first results of the interpretation of the optical imagery for the neighbouring area. In this case a Normalized Difference Vegetation Index (NDVI) time series (2016 to 2019) derived from Sentinel-2 data and processed with the BFAST (Breaks For Additive Season and Trend) algorithm

highlights different land-use patterns in agricultural and natural environments. Here, blue indicates a low number of changes whereas red stands for a high number of changes. Blue areas are interpreted as having a constant vegetation cycle over the entire time span: A few red areas apparently exhibit numerous changes in vegetation development, pointing to numerous crop changes. Colors in the natural vegetation are less pronounced and range from blue to yellow. Interpretation of the latter areas hints at changes in the natural vegetation cycle. These areas need to be investigated in greater detail in order to find out if soil or land degradation plays a role.

PROJECT STRUCTURE AND PARTNERS

Structured into four subprojects (SP) we investigate in close cooperation with South African partners the following major land degradation issues: current soil erosion (SP1) and long-term geological erosion (SP3), remote-sensing-based land-surface change and degradation (SP1, SP4) and land-surface-atmosphere interactions (SP2). The joint project is coordinated by the Friedrich Schiller University Jena and includes in Germany scientists from the universities in Jena (SP1), Augsburg (SP2) and Tübingen (SP3) as well as from the German Aerospace Agency (DLR); (SP4). A number of academic and institutional partners in South Africa support the research and provide intellectual input, logistic support and critical assessment of project outcomes (Fig. 4).

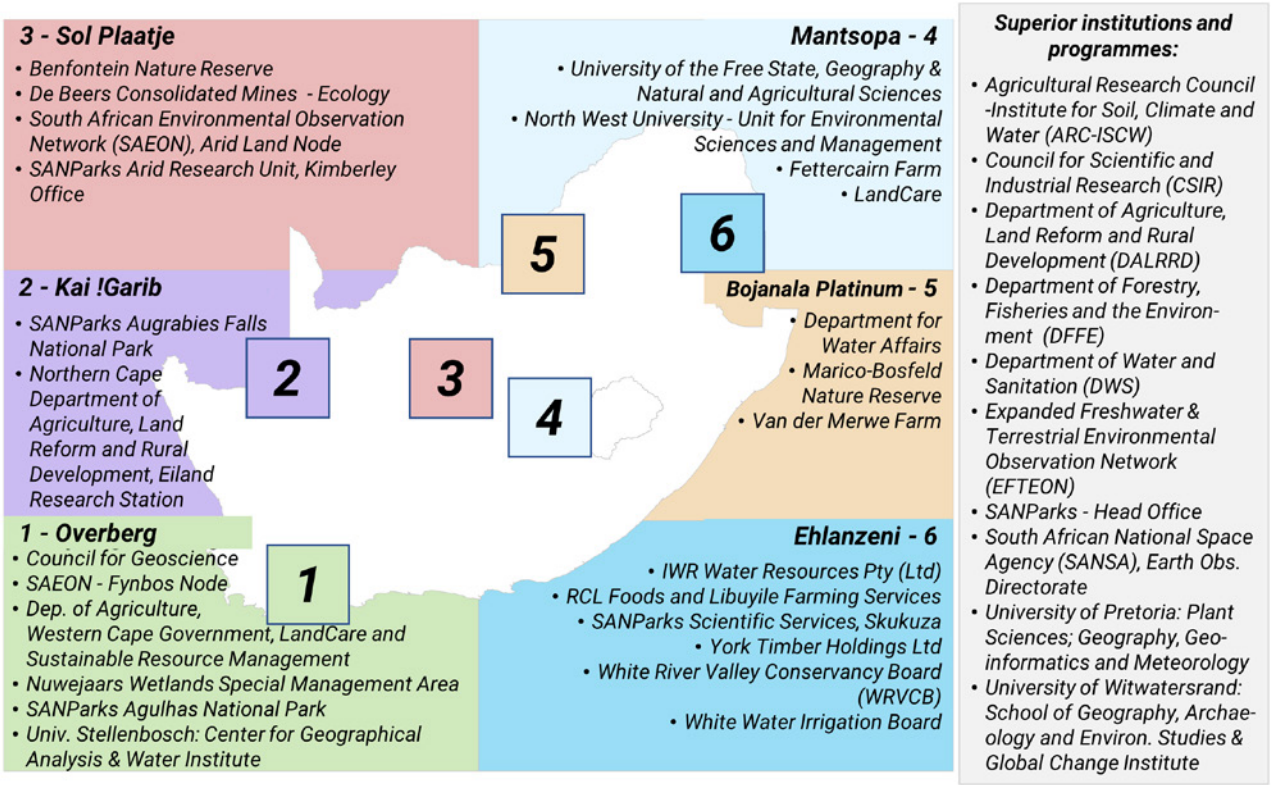


Fig. 4: SALDi stakeholder network in South Africa.

SALDI – SOUTH AFRICA LAND DEGRADATION MONITOR

COORDINATION:

Friedrich Schiller University Jena (FSU):
Institute of Geography

CONTACT:

PD Dr. Jussi Baade
jussi.baade@uni-jena.de

Institute of Geography
Friedrich Schiller University Jena
Löbdergraben 32
07743 Jena, Germany

PROJECT PARTNERS:

- Augsburg University:
  Institute of Geography
  Augsburg, Germany
- Eberhard Karls University of Tübingen:
  Department of Geosciences
  Tübingen, Germany
- German Aerospace Center (DLR)
  Oberpfaffenhofen, Weßling, Germany
- Agricultural Research Council (ARC):
  Institute for Soil, Climate and Water (ISCW)
  Pretoria, South Africa
- South African National Parks (SANParks):
  Headquarters and Regional Scientific Services
  Pretoria, South Africa
- Council for Scientific and Industrial Research (CSIR)
  Pretoria, South Africa
- South African National Space Agency (SANSA):
  Earth Observation
  Pretoria, South Africa
- Universities of Bloemfontein, Cape Town,
  Pretoria, Stellenbosch, Witwatersrand (Wits)
  South Africa
- Department of Agriculture,
  Land Reform and Rural Development (DALRRD)
  Pretoria, Südafrika
- Department of Forestry, Fisheries and the Environment (DFFE)
  Pretoria, Südafrika
- Department of Water and Sanitation (DWS)
  Pretoria, South Africa
- Eskom:
  GIS Centre of Excellence (GIS CoE)
  Johannesburg, South Africa
- South African Environmental Observation Network (SAEON):
  Expanded Freshwater and Terrestrial Environmental
  Observation Network (EFTEON)
  Pretoria, South Africa
- White Waters Irrigation Board
  Mpumalanga, South Africa
- White River Valley Conservation Board (WRVCB)
  South Africa

WEB PAGE:

saldi.uni-jena.de/en

SPACES II CAPACITY BUILDING

Capacity building is a central aim of SPACES II. BMBF, together with the German Academic Exchange Service (DAAD), initiated a Capacity Building/Development (CaBuDe) programme to enable southern African scholarship holders' research visits, networking and further education in Germany as well as equivalent activities of German scholarship holders in southern Africa. In addition, a programme of workshops and summer/winter schools was established by the SPACES II projects under a joint umbrella.

DAAD grants are awarded to African and German researchers associated with SPACES II projects and working on the fields of environmental, earth, coastal and marine sciences. The different types of grants in the CaBuDe programme comprise:

- PhD fellowships in Germany (up to 52 months)
- bi-nationally supervised doctorates: integrated research phase of PhD fellowship in Germany (6 to 24 months)
- short-term research fellowships for bachelor students, master students, PhD students, postdoctoral researchers and senior experts (two weeks to three months)

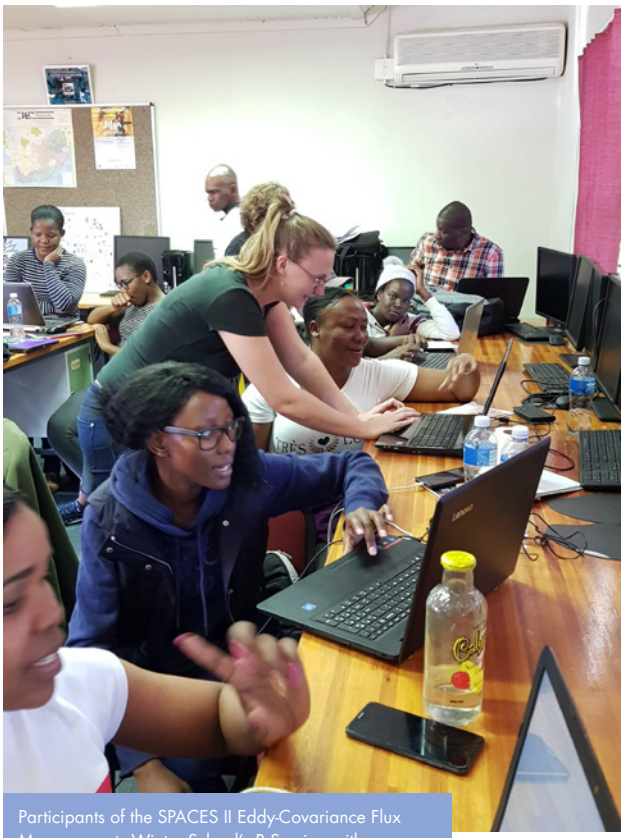
A total of six doctoral researchers from South Africa, Namibia and Zimbabwe were awarded the four-year PhD fellowship, starting their research associated with SPACES II projects in early 2020. Additional short-term research grants are awarded until 2024 to allow travel to Germany for exchange and networking with project partners.

The SPACES II Integrated Training Programme comprises nearly 30 summer/winter schools and workshops on key project skills and competencies. The programme aims to link the capacities of the southern African and German research communities and offers hands-on training in key topics such as modelling, greenhouse gas measurements, earth observations, ecosystem assessments and field-surveying methods. Most courses take place on the SPACES II project field sites in South Africa and Namibia. All courses are planned and organized collaboratively between the South African and/or Namibian as well as the German partners. Funded scholarships are available for southern African participants while many of the courses are also open for German participants.

The terrestrial projects' training programme is coordinated by the Thünen Institute of Climate-Smart Agriculture under the SPACES II Board and Steering Committee. The training programme is aligned with and runs in collaboration with other southern African regional initiatives, in particular SASSCAL (Southern African Science Service Centre for Climate Change and Adaptive Land Management) and ACCESS (Applied Centre for Climate and Earth Systems Science). The DAAD

coordinates the marine projects' training courses and summer schools via its CaBuDe programme. As a result of travel restrictions due to the COVID-19 pandemic, many courses of 2020 had to be run
as webinars or postponed to the following year.

SPACES II aims to create incentives for effective networking also by inviting and participating early-career researchers to its meetings and events. Special initiatives are designed by the early-career researchers themselves and workshops on key themes are organized by SPACES II senior researchers to strengthen the transferable as well as technical skills. SPACES II publishes a regular Newsletter which particularly welcomes inputs from early-career researchers.



Participants of the SPACES II Eddy-Covariance Flux Measurements Winter School's R Session with course assistant Tamryn Hamilton (SAEON; middle, standing).

Participants of the SPACES II Eddy-Covariance Flux Measurements Winter School at one of the hands-on sessions with course teachers Christian Brümmer (Thünen Institute; middle) and Amukelani Maluleke (SAEON/University of Stellenbosch; second from left) of EMSAfrica.

CONTACT:

Irmgard Kasperek
spaces-cabude@daad.de

German Academic Exchange Service (DAAD)
Kennedyallee 50

Dr. Mari Bieri
ak-spaces@thuenen.de

Thünen Institute of Climate-Smart Agriculture
Bundesallee 68
38116 Braunschweig, Germany

WEB PAGE:
www.spaces-training.org

SPACES II PROGRAMME MANAGEMENT

Dr. Elisabeth Schulz
Project Management Jülich (PtJ)
Forschungszentrum Jülich GmbH
Schweriner Straße 44
18069 Rostock, Germany

Dr. Olaf Pollmann
Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR)
German Aerospace Center
DLR Project Management Agency (DLR-PT)
Heinrich-Konen-Str. 1
53227 Bonn, Germany

Irmgard Kasperek
German Academic Exchange Service (DAAD)
Kennedyallee 50
53175 Bonn, Germany

SPACES II PROGRAMME PARTNERS

SOUTH AFRICA

Department of Science and Innovation (DSI)
Building 53, CSIR Campus
Meiring Naudé Road
Brummeria, Pretoria
Private Bag X894, Pretoria, 0001

Applied Centre for Climate
and Earth Systems Science (ACCESS)
ACCESS Pretoria Office
Building 33, CSIR Campus
Meiring Naudé Road
Brummeria, Pretoria

NAMIBIA

Ministry of Higher Education,
Technology and Innovation (MHETI)
Government Office Park (Luther Street)
Private Bag 13406
Windhoek

National Commission on Research,
Science & Technology (NCRST)
Cnr, Louis Raymond & Grant Webster Street
Private Bag 13253
Windhoek

GERMANY

Federal Ministry of Education and Research (BMBF)
Division Marine, Coastal and Polar Research
Division Global Change; Climate Research
53170 Bonn

LIST OF ABBREVIATIONS

ABM	Agent-Based Model
AFS	Agroforestry System
BCC	Benguela Current Convention
BISMOP	Biome Shift Monitoring Phytometer
DVM	Dynamic Vegetation Model
CO_2	carbon dioxide
EBUS	Eastern Boundary Upwelling System
ESA	European Space Agency
ESACW	Eastern South Atlantic Central Water
FONA	Research for Sustainable Development (Forschung für Nachhaltige Entwicklung)
GPS	Global Positioning System
in situ	on site, locally
IPCC	Intergovernmental Panel on Climate Change
nBUS	northern Benguela Upwelling System
NDVI	Normalized Difference Vegetation Index
POPs	persistent organic pollutants
RESM	Regional Earth System Model
RGB	Red, Green, Blue (color model)
SACW	South Atlantic Central Water
SAEON	South African Environmental Observation Network
SANParks	South African National Parks
SASSCAL	Southern African Science Service Centre for Climate Change and Adaptive Land Management
sBUS	southern Benguela Upwelling System
SDGs	Sustainable Development Goals of the United Nations
SP	subproject
SSTa	sea-surface temperature anomaly
UAV	Unmanned Aerial Vehicle
UN	United Nations