Programme	Title of the Project and research team	Project Overview	Objectives/ Outcomes

Earth Systems Science Research Programme (ESSRP) Global change is universally recognised as a complex challenge to the well-being of societies and the environment. The development and spread of technology seeking to advance socio-economic development now affects the fundamental functioning of this planet. The consequences and implications are, however, hard to predict. The observed impacts on the global climate and the biosphere are wide-ranging and has adverse effects on socio-economic well-being. Environmental change, driven by both natural and socio-economic drivers of change, is also undermining the resilience of the natural world, and reducing its capacity to support human quality of life. These impacts are often felt by the poorest in society, with emerging, developing and least developed economies most vulnerable.

Global change is therefore a significant risk to the developing world. The majority of the science being done to understand it however is done in the developed world, and in the Northern Hemisphere. As a result, several global-change related questions of critical importance to emerging and developing economies in the southern hemisphere are not adequately addressed. ESS provides an appropriate framework within which scientific work can be done to provide urgently needed understanding on the biophysical aspects of global change as well as an effective and exciting platform to encourage the youth to train for careers in science and technology.

South Africa also has a particular set of strategic advantages as a geographical base for an Earth System Science Research Programme (ESSRP). These include its geographical position at the southern tip of the African continent with globally important ocean interactions and strong tropical-extratropical regional interactions that drive rainfall and temperature patterns over the country (See Figure 1), strong climatic gradients that underpin its ecology and agricultural economy, extraordinary biodiversity both marine and terrestrial, diverse vegetation structure and faunal composition that is both representative of Africa as a whole, but also unique in Africa, large protected areas conserving the last of the world's major mammal assemblages providing key insights into the ecology of systems before mass extinctions and the rise of the Anthropocene, and an emerging economy in transitions of various kinds. South Africa is also subject to the early impacts of global climate change that appear to be interacting with natural long term climate variability that has been an historical feature impinging upon this region. Equally important is that South Africa boasts world class research and academic institutions that have made significant contribution to advancing our understanding of the earth system. Taken together, these features offer almost unparalleled opportunities for contributing to knowledge advances in ESS that will be beneficial both nationally and internationally.

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ESSRP	1. The impact of increasing woody vegetation cover on the supply of freshwater: catchment studies for national assessments and global models. **Research Team:** • Anthony Swemmer, SAEON • Michele Toucher, SAEON • Nicky Allsopp, SAEON • Alistair Clulow, University of KWaZulu-Natal • Ralph Clark, University of the Free State • Dominic Mazvimavi, University of the Western Cape • Michael Powell, Rhodes University **Project Start Date:** 2019 **Contact Details of the Project Leader:** Dr Tony Swemmer tony@saeon.ac.za 013 735 3534	- While there is much concern about deforestation around the world, the abundance of trees has increased over most parts of South Africa over the past century. Three of the major biomes of the country support a greater cover of trees and shrubs than before, due to afforestation, the spread of alien plants, disruption of fire and herbivory patterns, and possibly increases in atmospheric CO_2. This large-scale environmental modification is can lead to losses of biodiversity, and a reduced supply of freshwater (trees generally use more water than other plants, leading to less water infiltrating into the soil and ultimately into rivers).	- The objectives of this project are to: 1) determine the impact of increased tree cover on biodiversity and water supply, by using existing long-term, catchment-scale research sites. And 2) scale up site-specific vegetation and hydrological studies to simulate increased evapotranspiration and reduced river flows at local, regional and national scales.
	2. A Framework to Assess Global Change in Estuaries: Past, Present and Future	- Our work focusses on estuaries and the development of methods to better understand and predict estuarine ecosystem	- We aim to advance knowledge on the interaction between biodiversity and ecosystem resilience by establishing

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	Research Team: Prof. Ursula Scharler (University of KwaZulu-Natal) Dr Ntuthuko Masikane (University of Zululand) Prof Hendrik Jerling (University of Zululand) Mrs Fiona MacKay (Oceanographic Research Institute) Dr Susan Taljaard (CSIR) Mr Steven Weerts (CSIR) Dr Brent Newman (CSIR) Dr Lara van Niekerk (CSIR) **Project Start Date:** 2019 **Contact Details of the Project Leader:** Prof Ursula Scharler Email: Scharler@ukzn.ac.za	health and resilience under future global change scenarios. - Our team comprises ecosystem modellers, ecologists, ecotoxicologists, water quality and hydrodynamic modellers, as well as LULC modellers. Specifically, we investigate how hydrodynamics, water and sediment quality and ecosystem dynamics translate into health and resilience metrics at various scales (population, community, ecosystem, landscape), how changes in biodiversity influence ecosystem resilience, and understand how anthropogenic impacts (including global change scenarios, ecotoxicology,…) influence the estuarine ecosystem relative to natural variability.	quantitative links between estuarine biota, estuarine food webs, estuarine and river water quality, estuarine and river catchment land use and land cover changes (LULC), and climate change scenarios.
	3. Carbon dioxide capture, storage and encapsulation into methane hydrates **Research Team:** Prof Prathieka Naidoo(Grant holder and Project leader) Dr Saeideh Babaee (Senior Researcher)	- The focus of the experimental study is the encapsulation of carbon dioxide in the methane hydrate cavities in the presence of synthetic porous media (silica gel) and promoters. A pilot scale rig is being commissioned to test this concept, along with energy storage options. The project work scope also includes the investigation into alternate novel solvents for carbon	- The project aims to propose novel technology solutions for the capture, storage or conversion of carbon dioxide from flue gas emissions. A possible solution for the captured carbon dioxide is to store these as hydrates. Methane hydrates in deep ocean sediments can be replaced by carbon dioxide

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	Dr Hamed Hashemi (Senior Researcher) All based at: Thermodynamics Research Unit , School of Engineering, University of KwaZulu-Natal **Project Start Date:** 2019 **Contact Details of the Project Leader:** Prof Prathieka Naidoo Email: naidoop18@ukzn.ac.za	capture and the conversion thereof, with one study considering the use of bioreactors. Molecular dynamics (MD) simulation studies based on chemical quantum calculations as well as conductor-like screening model for real solvents (COSMO-RS) were developed. The solvent behaviour during carbon capture is assessed using these COSMO-RS and MD simulations.	
	4. Resilience of regulatory ecosystem services in wetlands: factors impacting upon sediment trapping and phosphate assimilation **Research Team:** Dr Suzanne Grenfell, Stellenbosch University Dr Bennie van der Waal, Rhodes University Nancy Job, Freshwater Biodiversity Programme, SANBI **Project Start Date:** 2019 **Contact Details of the Project Leader:** Dr Suzanne Grenfell Email: sgrenfell@sun.ac.za	- Fine sediment accumulates in wetlands resulting in downstream improvements in water quality. The aims of this research include estimating the sediment flux above, within and below wetlands, investigating catchment and wetland factors that affect sediment flux and investigating the seasonal variation in bio-available phosphates attached to sediment. Overall, the project aims to measure and estimate actual ecosystem service delivery and then determine, using an earth systems science approach, the relative importance of various local and catchment factors.	- The project will allow us to develop insight into the resilience of ecosystem service provision under various climate change or catchment management.

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	5. First African-based Earth System Model and the Southern Ocean **Research Team:** Prof. Francois Engelbrecht (PI; Wits GCI) Dr. Pedro Monteiro (Co-PI; CSIR SOCCO) Prof. Marcello Vichi (Co-PI; UCT MARIS) Prof. Hector Chikoore (Co-PI; UniVen/NWU) Miss Alice Lebehot (Science communication and training; UCT MARIS/CSIR SOCCO) Dr. John McGregor (Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia; collaborator) Dr. Marcus Thatcher (CSIRO, collaborator) **Project Start Date:** 2019 **Contact Details of the Project Leader:** Prof. Francois Engelbrecht Email:Francois.Engelbrecht@wits.ac.za Tel: +27 11 717 6098	- The SOCCESM project explores some of the unsolved scientific mysteries of the Southern Ocean, through the development of an African-based Earth System Model (ESM). The Southern Ocean is of critical importance in the global carbon cycle and the absorption of atmospheric CO_2, as well as heat. However, global climate models (GCMs) exhibit several biases in their representation of Southern Ocean carbon and heat fluxes, including in their seasonality. Around Antarctica, biases also exist in terms of how climate models represent the seasonal cycle of sea-ice. These biases suggest that some fundamental physical processes working in the Southern Ocean are inadequately represented in GCMs. In this project, we make use of high-resolution ocean models and machine learning to explore in great spatial detail the submesoscale processes working in the Southern Ocean – processes that are unresolved at the typical spatial resolutions of GCMs. Our aim is to obtain an enhanced mechanistic and/or statistical understanding of these processes, towards their improved parameterization in GCMs. In particular, we intend to build these parameterisations into a new global ocean model being developed through the project	- From this basis, we will proceed to simulate the impact of the Southern Ocean on southern African climate in a warmer world. The project has a strong focus on human capital development, and is not only developing a new climate model, but also a new cadre of climate modellers that are to live and work in Africa.

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		research, and the new African-based ESM it is embedded within.	
	6. The origin of southern African seasonality Research Team: Prof. Bob Scholes (PI, Wits GCI) Prof. Francois Engelbrecht (Co-PI; Wits GCI) Prof. Sally Archibald (Co-PI; Wits APES) Prof. Marion Bamford (Wits ESI) Prof. Hector Chikoore (Co-PI; UniVen/NWU) Mr. Ramapulana Nkoana (CSIR, researcher) Dr. John McGregor (CSIRO; collaborator) Dr. Marcus Thatcher (CSIRO, collaborator **Project Start Date:** 2019 **Contact Details of the Project Leader:** Prof. Francois A. Engelbrecht Email: Francois.Engelbrecht@wits.ac.za	- The project aims to answer the question: what conditions and mechanism led to the onset of wet-dry annual seasonality in southern Africa in the late Miocene? This form of annual seasonality, much less-studied than the cold-warm seasonality dominant at high-latitudes, was seminal in creating the savanna environments which occupy two-thirds of Africa, and lead to the rise to dominance of key plant and animal species and functional groups, and eventually the evolution of hominids. Our hypothesis is that the conditions for wet-dry seasonality were ultimately set up by plate tectonics, which led to a falling CO_2 concentration in the atmosphere, gradual aridification of the continent and the formation of a particular 3-basin oceanic circulation regime, with a warm current to the east and a cold current to the west of Africa, drawing the inter-tropical convergence southwards in summer and locking in a high pressure cell in the winter months. The seasonality was then reinforced by a feedback loop involving frequent, but low intensity, grass-fuelled fires, with global climatic consequences vial aerosol	- First we are assembling and synthesizing a paleo-ecological dataset based on multiple proxies to provide clues on the distribution of ecosystems in the subcontinent back to the mid-Miocene. Secondly, we are developing a dynamic land surface representation containing the key, novel plant functional types that came to dominate in the Pleistocene. Finally we are performing and analyzing climate-ocean-land simulations using global climate models, parameterized with the continental configurations, atmospheric composition and orbital forcings of the time, representing carefully selected periods over the past 10 million years, spanning the period when wet-dry seasonality began.

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		production. We are exploring this hypothesis using three, interconnected approaches.	
	7. Biodiversity and Ecosystem Functioning in Water Limited Ecosystems Under Climate Change **Research Team:** Midgley, GF, Stellenbosch University Henschel, J, SAEON (Desert Node) Abedowale, A. Sol Plaatje University Mazvenavi, D University of the Western Cape **Project Start Date:** 2019 **Contact Details of the Project Leader:** Prof Guy Midgley Email: gfmidgley@sun.ac.za	- The main aims of this proposal are to determine how biodiversity in semi-arid ecosystems is related to the resilience of ecosystem function under climate variability, and to project how biodiversity and ecosystem function in these systems may be affected by a changing climate.	- The project pioneers the application of close-distance remote sensing techniques to determine plant productivity behaviour from the time scale of minutes to an entire season.
	8. Sustainable Water Resource Management in Southern Africa **Research Team:** Cathy Clarke, PI (SU) Michele Francis, (SU) Eric Mashimbye,(SU) Shayne Jacobs, (SU	- The central goal of this project is to understand how climatic drivers impact water quantity and quality along the western margins of South Africa. The project has a focus on regions of ecological sensitivity as well as where rural development is hindered by the availability of water resources. The Olifants/Doorn, which is an ecologically	- The objectives of the project will be to use isotope tracers of water sources, pathways and timescales and to combine this with tracers of vadose zone contributors to groundwater salinity, particularly possible biogeochemical drivers. The results will be incorporated into water balance modelling to

Programme	Title of the Project and research team	Project Overview	Objectives/ Outcomes
	Andrew Watson,(SU) Sumaya Israel, (UWC) Dr Sven Kralisch, (Friedrich Schiller University Jena, Germany) Dr Annike Kunne, (Friedrich Schiller University Jena, Germany) Dr Laszlo Palscu, (Isotope Climatology and Environmental Research Centre, Debrecen Hungary) **Project Start Date:** 2019 **Contact Details of the Project Leader:** Cathy Clarke Email: cdowding@sun.ac.za	sensitive region, and the Buffels River, which is limited by water resource availability and quality, will form the main study areas.	understand ecological reserves requirements in the different systems and to use this information to evaluate the sustainability and vulnerability of groundwater under different climate change scenarios and how this will influence groundwater depletion and biodiversity loss in the two water management areas.
	9. The impact of increasing woody vegetation cover on the supply of freshwater: catchment studies for national assessments and global models. **Research Team:** Prof Shayne Jacobs, Stellenbosch University (sjacobs@sun.ac.za) Dr Marcellous Le Roux, Stellenbosch University (mrl@sun.ac.za) Prof Hugh Patterton, Stellenbosch University (hpatterton@sun.ac.za)	- While there is much concern about deforestation around the world, the abundance of trees has increased over most parts of South Africa over the past century. Three of the major biomes of the country support a greater cover of trees and shrubs than before, due to afforestation, the spread of alien plants, disruption of fire and herbivory patterns, and possibly increases in atmospheric CO_2. This large-scale environmental modification is can lead to losses of biodiversity, and a reduced supply	- The objectives of this project are to: 1) Determine the impact of increased tree cover on biodiversity and water supply, by using existing long-term, catchment-scale research sites. 2) scale up site-specific vegetation and hydrological studies to simulate increased evapotranspiration and reduced river flows at local, regional and national scales

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	Dr Jan Greyling, Stellenbosch University (jancg@sun.ac.za) Dr Johann Strauss, Elsenburg Agricultural Research Centre (JohannSt@elsenburg.com) Dr Thulani Makhalanyane, University of Pretoria (thulani.makhalanyane@up.ac.za) Prof Angel Valverde, University of the Free State (Bloemfontein Campus) (ValverdePortalA@ufs.ac.za) Dr Riana Jacobs-Venter, Agricultural Research Council (South Africa), Plant Protection Research Institute (JacobsR@arc.agric.za) Dr Cobus Visagie, Agricultural Research Council (South Africa), Plant Protection Research Institute (VisagieC@arc.agric.za) Prof J Dames, Rhodes University (j.dames@ru.ac.za) Dr Bronwyn Kirby-McCullough, University of the Western Cape (bkirby@uwc.ac.za) **Project Start Date:** 2019 **Contact Details for Project Leader:** Prof Karin Jacobs Email: kj@sun.ac.za	of freshwater (trees generally use more water than other plants, leading to less water infiltrating into the soil and ultimately into rivers).	