Franco-German Fellowship Programme on Climate, Energy and Earth System Research

“Make Our Planet Great Again – German Research Initiative (MOPGA-GRI)”

Funded projects

Field of research “Climate Change“

Name	**Dr. Jed Kaplan**
Former residence	Switzerland
Nationality	American
German host institution	**University of Augsburg (Prof. Dr. Peter Fiener)**
Project title	**Feedbacks between land cover, people, and climate in the seasonally arid tropics (MONSOON)**
Description	The MONSOON project asks the question: How do climate change and human activities combine to influence the risks of environmental and social disruption? Addressing this question is critical if we want to develop strategies to ensure the resilience of people and nature in the face of ongoing climate change. Yet our knowledge of the way landscape influences weather, and how human activities affect local and regional climate, is severely limited. The project will focus on the seasonally arid tropics, where the relationship between land surface conditions and regional climate is known to be very important, but where computer simulations perform poorly and characterizations of land use are overly simplistic, and where large populations with high demographic growth place societies at risk of future environmental and demographic tipping points. The MONSOON research team will use a combination of novel field studies and state of the art computer simulations to investigate land-climate interactions in South Asia and West Africa, two regions that are currently undergoing large-scale changes in land cover and climate that put societies at risk of disruption. The project study regions cover gradients in both the properties of the physical environment, such as rainfall and soil type, and

	sociocultural characteristics, such as population density and economic systems, that will allow us to identify places and land use strategies that put people and ecosystems at risk. We will make a significant advance in computer simulations of land cover and land use in seasonally arid climates, and better quantify the way land cover influences climate in these regions. The project builds upon Dr. Kaplan's long experience in land surface and climate modeling, and expertise in meteorology, land use, and soil science in the Department of Geography at the University of Augsburg. The project will further benefit from cooperation with the new Faculty of Human Medicine at the University of Augsburg, particularly through their research focus in Environmental Health Science.

Name	**Dr. Matthias Tesche**
Former residence	Great Britain
Nationality	German
German host institution	**Leipzig University (Prof. Dr. Johannes Quaas)**
Project title	**Particles in Aerosol Cloud Interactions: Stratification, CCN/INP concentrations, and Cloud Lifecycle (PACIFIC)**
Description	Atmospheric aerosol particles are of great importance for cloud formation in the atmosphere because they are needed to act as cloud condensation nuclei (CCN) in liquid-water clouds and as ice nucleating particles (INP) in ice-containing clouds. Changes in aerosol concentration affect the albedo, development, phase, lifetime and rain rate of clouds. These aerosol-cloud interactions (ACI) and the resulting climate effects have been in the focus of atmospheric research for several decades. Nevertheless, the IPCC still concludes that ACI cause the largest uncertainty in assessing climate change as they are understood only with medium confidence. PACIFIC will improve our understanding of ACI by enhancing the representation of the aerosols relevant for cloud processes and by quantifying temporal changes in cloud properties throughout the cloud life cycle. ACI studies using polar-orbiting sensors are limited to snap-shot observations of clouds. CCN concentrations for assessing ACI are currently estimated from column-integrated optical aerosol parameters. There is no such proxy of INP concentrations for remote-sensing studies of aerosol effects on cold clouds as INP activity depends on aerosol type and size. Quantifying the role of aerosols in ACI requires knowledge of the spatial and vertical distribution of CCN and INP. I will use my experience in advancing state-of-the-art lidar retrievals to obtain unprecedented insight in CCN and INP concentrations from spaceborne lidar data. In addition, I will characterise the development of clouds before and after the snap-shot view of polar-orbiting sensors by tracking those clouds in time-resolved geostationary observations. This novel information will be used to study the effects of CCN and INP on the albedo, liquid and ice water content, droplet and crystal size,

	development, phase and rain rate of clouds within different regimes carefully accounting for the meteorological background. The findings of PACIFIC are crucial for assessing and improving the performance of climate models.

Name	**Dr. Anna Possner**
Former residence	USA
Nationality	German
German host institution	**Goethe University Frankfurt (Dr. Bettina Heiss)**
Project title	**Organisation and Cloud-Radiative Properties of Low-Level Mixed-Phase Clouds**
Description	Clouds, which reside close to the ground are good reflectors of incoming sunlight and trap little heat radiated outward to space. In some sense these clouds shade the Earth's surface and changes in cloud area or changes in their reflective properties constitute a pretty sensitive temperature dial for Earth's climate. Any sheet of low-level cloud may span hundreds of kilo-meters and all together they span around one fifth of Earth's oceans. In some regions of the globe, in the mid-latitudes and the Arctic, these clouds do not only consist of water drops, but may contain a mixture of ice particles and water drops. We, as a community, are currently limited in our understanding of how the presence of ice crystals impacts the areal coverage and reflective properties of these clouds at the scale of an entire cloud field as opposed to a single cloud. To answer this question, we will use satellite retrievals and sophisticated numerical models, which resolve many of the fundamental processes governing the cloud evolution.

Name	**Dr. Clemens Scheer**
Former residence	Australia
Nationality	German
German host institution	**Karlsruhe Institute of Technology (KIT, Prof. Dr. Klaus Butterbach-Bahl)**
Project title	**Climate change, reactive nitrogen, denitrification and N^2O: Identifying sustainable solutions for the globe**
Description	The use of synthetic N fertilizers has grown over the last century, with severe environmental consequences. Denitrification will ultimately remove most of the anthropogenic reactive nitrogen (Nr), but it is very uncertain in which degrees this process will take place. Denitrification will also need to be seen in the light of the conflict between a growing world population which requires intensified crop production and an augmented use of fertilizers which in turn would lead to increased emissions of greenhouse gas (GHG) and nitrous oxide (N2O) from man-aged soils.

	The project aims to initialize and strengthen global research networks on denitrification, establishment of a missing global database, and to reduce uncertainties of current model estimates.

Field of research "Energy Transition"

Name	**Dr. Andreas Goldthau**
Former residence	Great Britain
Nationality	German
German host institution	**Potsdam Institute for Advanced Sustainability Studies (IASS) / Prof. Dr. Mark G. Lawrence**
Project title	**Investigating the systemic impacts of the global energy transition (ISIGET)**
Description	The global energy transition is already delivering numerous benefits, but it is also creating new inequalities. The risks posed by this transformation will impact especially on developing countries, which lack access to technologies and capital. What, then, can be done to ensure that these countries too can make the transition to a low-carbon economy? This question is the focus of the ISIGET project that will study the systemic impacts of the global energy transition. ISIGET will be led by Prof. Andreas Goldthau, a renowned global public policy scholar of Royal Holloway, University of London, who will head an interdisciplinary team of researchers at the Institute for Advanced Sustainability Studies (IASS), a leading climate research institute based in Potsdam. The energy transition is largely presented in a positive light. This, however, does not tell the entire story, explains Andreas Goldthau: "The energy transition throws up a range of systemic risks that are particularly pertinent to the countries of the Global South: investments in fossil-based sources of energy are no longer likely to be profitable over the longer term, while those holding patents to the technologies vital to a low-carbon economy will be at an advantage in future. However these patents are held almost exclusively by OECD countries and China. This research will highlight the adjustments that need to be made in order to ensure that the gains of the energy transition are distributed fairly." To this end, the project team will develop recommendations for new governance initiatives, with a view to reconciling conflicting policy goals. The researchers will begin by interviewing decision-makers from the finance and insurance industries and government agencies about their views on the systemic risks entailed by the global energy transition. In a next step, the team will conduct scenario

	analyses, factoring in the relative economic development, quality of institutions, and fossil resource wealth of select countries. These analyses will reveal the type and extent of macro- and socio-economic risks to which countries in the Global South in particular are exposed. Complementing these scenarios, the researchers will also carry out selected case studies in different global regions. These studies will include interviews with decision-makers from local businesses, corporate finance, and development agencies and banks. This will enable researchers to identify welfare effects, development impacts, and distributional effects as well as the financial and trade risks for different types of scenarios. In addition to publishing academic articles, the researchers will develop policy options for addressing the challenges facing developing nations in the context of the global energy transition. The results of this research will be fed into the public debate in France, Germany and across Europe through the publication of policy briefs and articles in media outlets.

Name	**Dr. Heechae Choi**
Former residence	South Korea
Nationality	South Korean
German host institution	**University of Cologne (Prof. Dr. Sanjay Mathur)**
Project title	**Amorphous-crystal junctioned semiconductor: a new class of photocatalytic material with high activity and cost-effectiveness**
Description	This project is aiming at developing new class of semiconductor system, amorphous-crystal junction, for effective charge carrier separations. In electronic devices and electrochemical applications, charge carrier separable functionality of semiconductors is widely utilized. Conventionally used p-n junction and heterojunction semiconductors are fabricated via complicated processes, and hence, many factors such as dopant selections, precursors, and CVD conditions must be considered. Therefore, in spite of strong impact of junctioned semiconductor materials, the commercialization of such materials hardly makes both ends meet. In this project, I suggest a breakthrough idea: amorphous-crystal junction of semiconductors can be utilized as good alternatives of many of p-n junctioned and heterojunctioned. When a semi-conductor material changes its crystal structure, the band edge levels are also changed. If we consider amorphous semiconductor solid as one of the phases, we can make heterojunction- or p-n-junction- like material just by partially amorphizing semiconductor solids or stopping crystallization process in the middle.

Name	**Dr. Michael Zürch**
Former residence	USA

Nationality	German
German host institution	**University of Jena (Prof. Dr. Christian Spielmann)**
Project title	**Quantifying ultrafast non-equilibrium dynamics in semiconductor quantum nanomaterials (QUESTforENERGY)**
Description	Nanointegration and efficiency optimization of silicon-based devices clearly reached the end of the road while advancing society requires ever-increasing capacities of communication and computation and, thus, electric power. At the same time, the efficiency of homojunction silicon solar cells is physically limited and the production of more efficient hetero- and multijunction silicon cells is technologically challenging and expensive, hampering the potential for effectively counteracting climate change while meeting the needs of the digital age for advancing society. Clearly, new materials that offer high efficiencies, low losses, new mechanic and optoelectronic properties at economic large-scale production capability must become a corner stone of the transformation of energy production, conversion and storage in the 21st century. A promising material class are novel semiconductor quantum nanomaterials that offer remarkable properties addressing these requirements. Many of these nanomaterials are more device-ready than the widely known graphene due to their optical bandgap. The intriguing possibilities stemming not only from low-loss charge transport combined with a design-able photo-optical response, but also the inherent nanoscopic dimensions of these materials blend ideally for future highly versatile and economic photonic devices. While the static optical and electronic properties of these materials are subject of current investigations, little is known about how these properties are altered when the systems are driven very rapidly out of thermal equilibrium by ultrafast optical excitation allowing for new electronic phases and physical effects. Studying and controlling the electronic and optical properties on the femtosecond level are paramount for designing future energy-efficient photonic devices. The goal of this research program is the time-resolved observation and control of the carrier and lattice dynamics in two-dimensional semiconductor materials driven out of equilibrium at femtosecond time scales. This interdisciplinary program interfaces between Material Science, Physical Chemistry, Optics and fundamental Physics. Studying the ultrafast photoresponse and directly observing the excitation followed by thermalization of the systems allows to predict fundamental limitations for devices, observing new quantum phases with potentially even enhanced properties and providing input for advanced modelling of these materials. Understanding and controlling the optoelectronic properties in these nanomaterials will pave the way for novel multijunction solar cells and highly efficient and highly integrated optoelectronic devices that will perform significantly beyond current silicon-based technology.

Name	**Dr. Eric Hill**
Former residence	USA

Nationality	American
German host institution	**Hamburg University of Technology (Prof. Dr. Gerold A. Schneider)**
Project title	**Nanocomposites and Materials for Energy Solutions**
Description	The current crisis facing our planet is significant: widespread overuse of fossil fuels threatens the globe through pollutants and greenhouse gases that can lead to catastrophic enviromental consequences. In the short-term, widespread extinctions, food shortages, and desertification are already occurring, but the longer-term outlook is even grimmer, with broader disruption of climate patterns and sea level rises slated to occur within the next few decades. The sun is our planet's principal source of energy, and when harnessed properly it can provide power without the negative effects of burning fossil fuels. In photocatalysis, light energy stimulates the breaking and/or formation of chemical bonds for the production of alternatives to fossil fuels (such as hydrogen gas) and degradation of environmental pollutants to less harmful constituents. In recent years it has become clear that direct conversion of light energy from the sun to chemical energy can be facilitated through advances in photocatalytic materials. This project seeks to investigate the chemistry at the interface of photocatalytic nanomaterials toward advancement of clean energy technologies. It is focused on their functional properties at the nanoscale, in which opportunities are wide open to understand the diffusion and clustering of intercalants and their interactions with materials at the interface. A multi-disciplinary approach involving both experiment and theoretical calculations will enable accurate predictions and detailed mechanistic explanations of experimental observations. Furthermore, lessons learned from the proposed work in hybrid semi-conductors and photocatalytic materials can be applied to other areas of energy involving intercalation chemistry, such as photovoltaics, solid-state batteries, and gas-separation membranes. Three separate approaches towards improved photocatalytic materials are undertaken in this project: (1) Hybrid nanostructures using a plasmonic component can enhance the efficiency of photocatalysis, and basic research into the fundamental roles of molecular aggregation on plasmonic nanoparticle growth on inorganic surfaces will be carried out. (2) The synthesis of nanoscopic semiconducting composites will contribute toward improvement of photocatalytic materials. (3) Formation of nature-inspired materials with ultra-thin semiconductors will foster development of mechanically robust functional materials with tunable transparency for photo-catalysis. Collectively, these studies will lead to the engineering of mechanically robust photo-catalytic materials with improved performance and low cost compared to the state of the art, in order to promote a carbon-free energy future.

Name	**Dr. Yutsung Tsai**
Former residence	USA
Nationality	Taiwanese
German host institution	**Helmholtz-Zentrum Berlin for Materials and Energy (Prof. Dr. Norbert Nickel)**
Project title	**Lateral multi-junctions of 2-D transition metal dichalcogenides as optoelectronic platform for transparent photovoltaics**
Description	The current solar energy conversion by established photovoltaic devices does not meet the renewable energy production targets necessary for mitigating climate change. Hence, it is necessary to develop new device systems that employ inexpensive semiconducting materials and that can be processed by simple scalable techniques into high-performance devices that are capable of stable operation. Recent advances with ultra-thin two-dimensional (2D) semi-conductors, transition metal dichalcogenides (TMDs), have suggested that their unique properties including tunable band gaps, light absorption, and large-area high-performance devices fabricated using scalable and inexpensive techniques can be leveraged for new device concepts. It is the aim of this project to develop 2D TMDs lateral multijunctions as nano-optoelectronic platforms to implement their favorable optoelectronic properties for a scalable production of transparent photovoltaics.

Field of research "Earth System Research"

Name	**Dr. Gayane Asatryan**
Former residence	Australia
Nationality	Armenian
German host institution	**Museum für Naturkunde - Leibniz Institute for Evolution and Biodiversity Science (Dr. David Lazarus)**
Project title	**Paleogene Polar Plankton and Productivity (the P4 Project)**
Description	Virtually all carbon dioxide (CO2) released to the atmosphere is eventually removed by the ocean's phytoplankton, which capture it as living tissues (organic carbon or skeletal materials) in the sunlit surface oceans; then when the plankton cells die and sink, export it into the deep ocean and ocean bottom sediments. This process, called the ocean carbon pump, is the only significant planetary long-term (centuries or longer) removal mechanism for CO2, as other forms of capture (e.g. land vegetation) only store carbon as long as the vegetation grows. Polar phytoplankton, particularly the silica-shelled diatoms, are particularly

	important in the carbon pump. The species dominating pump activity are mostly cold water forms and may become less effective, or in part even go extinct, if ocean waters warm to levels predicted by global warming climate models, thus damaging the pump and worsening global warming. The only analogs to such a future warm polar ocean are however found only in the distant geologic past, e.g. in the warm Eocene period, shortly before the oceans cooled into the following glacial Oligocene period. The P4 project will clarify how polar plankton, the carbon pump, and climate change interact via an integrated study across the Eocene-Oligocene boundary. Our goals are 1) to better understand how changes in oceanography and plankton evolution, particularly in polar regions, contributed, via changes in global ocean productivity and the earth's carbon cycle, to the dramatic cooling of global climate during this time interval; 2) to characterize how polar ocean productivity and the carbon pump functioned in the warm, high atmospheric pCO2 world, and 3) to identify environmental controls on silica-shelled plankton evolution and biodiversity, particularly extinction risks in plankton associated with major climate change. Our study uniquely blends paleoclimate and paleobiodiversity methods to understand the joint climate-biotic system. It also uniquely focusses on the most direct records of these events - the plankton and deep-sea sediments in polar regions, although we also include geochemical proxies of ocean conditions from low latitude regions, and syntheses of published global deep-sea sediment data. Diatoms are targeted but we also use radiolarians as these are well preserved, species rich, and highly sensitive to ocean conditions in both polar and tropical regions, including water depth specific marker species. Methods include tracing polar water mass development and intermediate water depth export of nutrients from poles to low latitude upwelling systems; global syntheses of ocean productivity via biogenic opal and carbonate export rates in ocean sediments; standard geochemical proxies (stable isotopes, element ratios) of ocean water conditions in both low and high latitudes; and biodiversity surveys of diatom and radiolarian biotas over time. Innovative technical tools will be used in the project, including advanced 3-D microimaging for radiolarian species taxonomy, "big-data" syntheses of global ocean sediment export via integration of global community science databases (Pangea, NSB), and ocean circulation models to place our data in a meaningful global oceanic context.

Name	**Dr. Christina Richards**
Former residence	USA
Nationality	American
German host institution	**University of Tübingen (Prof. Dr. Oliver Bossdorf)**
Project title	**Genomics and Epigenomics of Plant Invasion**

Description	In the context of climate change, understanding the mechanisms involved in species resilience is a critical issue for maintaining biodiversity and global sustainability. Massive human-mediated introductions of species outside their native ranges have resulted in global invasions with dramatic ecological and evolutionary consequences. By creating novel interactions with established species, invasive species can transform the physical habitat, as well as the evolutionary trajectories of plant, animal, and microbial species and communities including loss of local genetic diversity, change in community zonation patterns, and local extinction. Invasive species have endangered native species, and caused an estimated €1 trillion per year globally in economic losses according to the European Commission. Climate change is expected to increase risk from invasive species by enhancing challenging conditions and habitat disturbance. In this project, Associate Professor Richards (USF) will work with Professor Oliver Bossdorf at the University of Tübingen in Germany, and Professors Bo Li and Ji Yang at the University of Fudan in China to integrate genomics tools into field and experimental studies of the globally invasive Japanese knotweeds. The work will be done at the local (population, community) and intercontinental levels, and will provide unprecedented information about the mechanisms involved in species resilience and invasive abilities. The knowledge gained will be critical for recommendations to stakeholders in risk assessment and decision making for predicting, preventing and managing biological invasion. Using the globally invasive Japanese knotweed species as a model, their approach will address general questions about biological invasions and will provide knowledge that applies to other invasive species.

Name	**Dr. Henry C. Wu**
Former residence	USA
Nationality	American
German host institution	**Leibniz Centre for Tropical Marine Research (Dr. Agnes Richard)**
Project title	**Ocean Acidification Crisis and global warming observations from tropical corals (OASIS)**
Description	Human-induced global climate change is one of the biggest threats and concerns for our society and environment. The increase in atmospheric carbon dioxide levels are not only warming the Earth’s surface and ocean temperatures but are also increasing the acidity of our shallow marine environments. This process, known as ocean acidification, occurs because our oceans absorb massive amounts of the greenhouse gas carbon

	dioxide from the Earth's atmosphere. When excess carbon dioxide reacts with seawater, carbonic acid is formed and this results in the decrease of seawater pH that threatens the ability of calcifying organisms to build their functional skeletons. The consequences of decreasing ocean pH are severe for ecosystems because these calcifying organisms form the food-web foundation in shallow tropical oceans. Thus stresses in those ecosystems have also implications for global fishing economy. Project OASIS will investigate the development of ocean acidification because current understanding and scientific knowledge on the effects of ocean acidification in the tropics has so far been very limited. This is due to the lack of reliable long-term seawater pH monitoring and measurements as well as the difficulty in reconstructing past changes in pH and ocean chemistry in the oceans. Through the analysis of boron isotopes in long-lived massive tropical corals, the goal of Project OASIS is to determine the pH values of seawater in various geographical regions of the Atlantic, Pacific and Indian Oceans. Boron is a natural component of sea-water and its isotopes are sensitive to changes in ocean pH. Corals take in this seawater to form their calcareous skeleton and any change in pH can be detected in the boron isotopes incorporated in the coral skeleton. By determining the pH over the most recent few hundred years, Project OASIS will reconstruct the global development of ocean acidification and assess the rates of change in ocean chemistry of our tropical oceans before and after the Industrial Revolution. These results will provide valuable data to understand the process of carbon dioxide uptake into the oceans, the magnitude of global ocean acidification, and draw conclusions on the changing climate parameters. Furthermore, the scientific outcome of this project can provide important information to policymakers and stakeholders who are committed to mitigating the increase in atmospheric carbon dioxide and comprehend the impact of corrosive seawater on fragile marine calcifiers.

Name	**Dr. Helmuth Thomas**
Former residence	Canada
Nationality	German
German host institution	**Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research (Prof. Dr. Kay-Christian Emeis)**
Project title	**The Ocean's Alkalinity: Connecting geological and metabolic processes and time-scales**
Description	The project addresses the role of oceans as regulators of atmospheric carbon dioxide (CO2), thus making a crucial contribution to maintaining climate on Earth in a habitable range. This regulatory function is biogeochemically performed by the ocean's CO2 and pH buffer capacity: alkalinity. Alkalinity is generated by rock weathering, and by natural and human-induced anaerobic processes in sediments of coastal seas. The processes in coastal seas are related to eutrophication such that

	enhanced nutrient runoff increases alkalinity generation and the risk of deoxygenation and acidification. Climate change and its mitigation both have the potential to perturb the long-term stability of the ocean's alkalinity: ice traction will expose rock surface, hitherto covered, to weathering and erosion. Attempts to mitigate and lower atmospheric CO2 levels will necessarily involve the use bioenergy to a large extent, which turn comes with the need to massively employ fertilizers and its consequence: eutrophication and potentially alkalinization of coastal seas. Research will investigate in which measure and to which extent human activities and climate change affect the ocean's alkalinity, particularly the impact of nitrogen fertilizers on coastal seas including the subsequent risk of acidification and deoxygenation. The project will be carried out collaboratively with the Universities of Oldenburg, Hamburg and Exeter (UK), and the Alfred-Wegener-Institute for Polar and Sea Research.