

MAKE OUR PLANET GREAT AGAIN



THE LAUREATES

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ASATRYAN GAYANE 

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Project : *Paleogene Polar Plankton and Productivity (the P4 Project)*

Host institution : Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Berlin

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Virtually all carbon dioxide (CO₂) released to the atmosphere is eventually removed by the ocean's plankton, 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. It has been suggested that these species might become less effective, or in part possibly even go extinct, if ocean water temperatures increase by up to 6, or even 10 °C in polar regions. Temperature changes of this magnitude are predicted by 'high' emission scenarios in global warming climate models. Loss of carbon capturing plankton would damage the pump and worsening global warming. It is not possible to test plankton response only with current plankton observations, as modern oceans have yet to warm significantly, and realistic ocean plankton ecosystems can not be created in laboratory cultures.

We have studied fossil plankton behavior during the closest geologic analogs to such dramatic predicted future ocean temperature changes. The main focus of our study was the 33-38 million year old interval, where Antarctica became glaciated at the transition between the Eocene and Oligocene geologic epochs: the 'E/O' boundary event. We studied polar siliceous plankton and have found that much of the polar diatom and radiolarian plankton (an ecologically important group of ocean siliceous zooplankton) went extinct at the maximum magnitude of temperature change at the E/O. This has been estimated in other studies as having been between 6 and 10 °C. We also found that diatoms increased in abundance in polar oceans well before the E/O boundary, at the same time as deep sea sediment chemical markers show increased export of plankton into the ocean sediments. This lends support to the idea that the evolution of diatoms in polar regions increased removal of CO₂ from the Eocene atmosphere, helping to cool global climate, possibly triggering the glaciation of the E/O boundary. Some tropical sites were also studied for data correlation, particularly for radiolarian research. Radiolarian diversity counts were improved several times compared to NSB databas published results before our study. Several not described radiolarians were encountered in the studied material; 30 out of them were selected for publication as new species.

An article in collaboration with colleagues at the University of Nevada about more recent radiolaria has been published (Trubovitz et al., Nature Communications, 2020). The first manuscript from our E/O study will be submitted still this year (Rodrigues de Faria et al., in prep.). Several other manuscripts are in preparation.

Challenges in our study included the much higher than expected diversity of taxonomically unknown species found in our samples besides coronavirus related restrictions and extended home office, and limited access to the labs. This required substantially more time for primary taxonomic analysis than planned. Many samples had insufficient numbers of the fossil foraminifera typically used for chemical marker analyses. We were able to resolve this in part by very time consuming searches for rare specimens in samples. We also used a new, small sample bio-Barium chemical marker method that did not require foraminifera, and analyses of non-foraminifera (phytoplankton) sediment carbonate. The Ba analyses were done for us by Jessica Stammeier of the GFZ in Potsdam.

Our results in general suggest that if high emission scenarios come to pass, the magnitude of polar ocean warming could exceed a critical threshold and cause substantial extinctions in plankton, permanently damaging the ocean's ability to remove carbon dioxide from the atmosphere.



BALAJI VENKATRAMANI

Laureate of the French call

Home institution : USA, Princeton

Project : *HRMES – High-resolution Modeling of the Earth System*

Host institution : Laboratoire des sciences du climat et de l'environnement, Saclay

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Project Hermès has the key aim of addressing sources of uncertainty in our understanding of the Earth system and its variability and evolution under changes in external forcings. The uncertainty comes from our inability to resolve key processes relevant to climate: principally the role of clouds, but we hypothesize that similar approaches can be applied in the ocean for key mixing processes that are also below the current resolution threshold. The project can be summarized as follows:

Conduct very high-resolution simulations of key processes in the atmosphere and oceans which are below the threshold available in global models today. Such simulations will be at the limit of capability on today's computing technology. Given trends in computational technology, use these simulations to build and train fast approximate models of the Earth system, to explore uncertainties in the system using ensembles that are beyond possibility with the full model.



BALLANTYNE ASHLEY

Laureate of the French call

Home institution : USA, University of Montana

Project : *POMELO – Testing processes in Earth System Models with global satellite and atmospheric observations*

Host institution : Laboratoire des Sciences du Climat et de l'Environnement, Saclay

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One of the largest sources of uncertainty for climate predictions is due to carbon-climate feedbacks in Earth System Models (ESMs), where some ESMs indicate that land carbon (C) sinks will persist and others indicate that they may become C sources. For this reason the World Climate Research Program has identified carbon-feedbacks in the climate system as one of their grand challenges. To address this challenge, we have proposed three specific research objectives within the Process Oriented Model Evaluation – Linked to Observations (POMELO) project. (R1) We will combine satellite observations and atmospheric observations to resolve Net C Exchange (NEE) into its key processes of gross primary productivity and total ecosystem respiration ($NEE = GPP - TER$) to test their sensitivity to climate. (R2) To better diagnose processes leading to biased estimates of C turnover times in ESMs, we will evaluate how well ESMs perform at reproducing ^{14}C tracers in Earth's atmosphere, biosphere, and ocean to constrain turnover times of anthropogenic carbon.

(R3) We will also evaluate stomatal response to changes in climate and CO_2 in ESM simulations. It is apparent that ESMs use different stomatal functions in predicting vegetation response to changes in atmospheric CO_2 and H_2O vapor, which results in different rates of C uptake. All analyses in R1-R3 will be compared to the latest ESM simulations made available through the 6th Climate Model Intercomparison Project (CMIP6). By accomplishing these short-term research objectives, we wish to promote the long term goal of process oriented global model evaluation linked to global C cycle observations-POMELO.



BOUCHARD FRÉDÉRIC



Laureate of the French call

Home institution : Canada, Department of Applied Geomatics Université de Sherbrooke

Project : *Permafrost and Greenhouse gas dynamics in Siberia (PEGS)*

Host institution : Géosciences Paris-Saclay (GEOPS) Université Paris-Saclay France

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Permafrost is defined as any soil or rock with a temperature at or below 0°C for at least two consecutive years. Covering more than 20 million square kilometers in the northern hemisphere, permafrost is especially abundant and ice-rich in Yakutia (eastern Siberia). It contains millennium-old organic matter (plant and animal debris) deposited and sequestered in frozen soil during colder climate. With ongoing climate warming, this ice-rich permafrost thaws and releases organic carbon, which can then be transformed into greenhouse gases (CO₂, CH₄) by microbial processes. This project explores the dynamics of these greenhouse gases from a set of lakes of different origins near Yakutsk, eastern Siberia. The results show that these lakes are hotspots of greenhouse gas emissions, but with substantial spatial and temporal heterogeneity (differences up to two orders of magnitude depending on lake type and season). Shallow and old lakes located in hydrologically closed depressions act as CO₂ sinks and strong sources of CH₄ during some seasons, while recent 'thermokarst' (thaw) lakes are moderate to extremely high sources of CO₂ and CH₄, with considerable accumulation of greenhouse gas under the ice cover (winter) or in the deepest water layers (summer). Such spatial and temporal heterogeneity in greenhouse gas dynamics from permafrost lake-rich landscapes are currently not included in Earth system models. By providing urgently needed field and lab data to the modelling community, the PEGS project will hopefully contribute in structuring and consolidating the French Arctic science community and its international partners (e. g., Canada, USA, Germany) as a leader in climate change issues.



BOUCHARÉL JULIEN



Laureate of the French call

Home institution : USA, University of Hawaii

Project : *TROCODYN – Tropical Cyclone activity and upper-ocean Dynamics*

Host institution : Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, Toulouse

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Identifying and understanding the mechanisms involved in hurricane genesis and intensification is paramount to building reliable forecast systems that are beneficial for risk management agencies and coastal populations. The two main goals of the proposed study are 1) to assess and quantify the control of the upper-ocean dynamics on the variability of hurricane activity in the Eastern Pacific and Atlantic basins from intraseasonal to seasonal timescales, 2) account for these mechanisms to provide a theoretical basis crucial to upgrade physical-empirical forecast models. It is proposed to critically evaluate the most recent oceanic, atmospheric in-situ data, reanalyze products and storm track archives focusing on the following key questions: how much of the variability of cyclonic activity in these regions originates from changes in oceanic conditions? To what extent are these changes related to natural modes of oceanic variability? What can we learn from the relatively predictable tropical ocean dynamics to improve hurricane forecasts in these basins? Results derived from observation-based products and theoretical analysis will be confronted to output from state-of-the-art forced and coupled global and regional climate models. This will allow quantifying and comparing, via a variety of sensitivity experiments, the control of different timescales of oceanic variability on the cyclonic activity in these two basins. This research activity fits adequately the scope of the host institution LEGOS, involves numerous internal and external collaborations and will train a PhD student.



CAPRON EMILIE



Laureate of the French call

Home institution : Denmark, University of Copenhagen

Project : *HOTCLIM – CHaracterisation & dynamics Of pasT warm CLIMates*

Host institution : Institut des Géosciences de l'Environnement, Grenoble

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The anthropogenic-induced warming in the high latitude regions has global climatic implications due to polar ice mass loss, sea level rise and ocean circulation changes. To evaluate the risk of major current and future environmental changes, it is essential to understand climate, cryosphere and carbon cycle feedback processes that occurred during past time periods that were warmer than today. The HOTCLIM project will investigate the strength and variability of high-latitude climate during past warm periods, which exhibit a polar warming comparable to that projected by 2100 due to specific combinations of orbital and atmospheric CO₂ forcing. It is based on an approach combining gas analyses on the air trapped in ice cores drilled in Antarctica, climate data syntheses from marine and terrestrial archives, and comparison with outputs from state-of-the-art climate models. The HOTCLIM project will improve our understanding of (1) natural climate variability under orbital and CO₂ forcing and (2) of the response of polar ice sheets, sea level and ocean circulation to a prolonged warming. It will provide benchmarks to test climate model performance outside the short-term climate observation range and in a range of temperature changes comparable to projected future warming, hence helping improve climate projections.



CLARK JAMES



Laureate of the French call

Home institution : USA, Duke University

Project : *Forecasting Biodiversity Change (FORBIC)*

Host institution : Laboratoire des écosystèmes et des sociétés en montagne, Grenoble

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Future ecosystems will be shaped by forest capacity to recover from stress and adapt to accelerating change. Forests provide the structural foundation for much of the planet's biodiversity, and they deliver the resources needed to maintain food webs and many of the services on which humans depend. The MOPGA project Forecasting Biodiversity Change initiated a global effort to understand the changes happening now and their implications for biodiversity. Led by researchers at Duke University and INRAE/Univ Grenoble, the initiative now engages over 100 collaborators from Europe, North America, South America, and Asia.

Our initial focus on forest reproduction is expanding to effects on the consumers of forest productivity. Our early results have quantified the basic biogeography of fruit, seed, and nut production, how it is controlled by the condition of individual trees, and how those responses translate to landscape and continental shifts. Current focus on forest recovery and effects on wildlife extend the early MOPGA results to biodiversity impacts.



DERRY LOUIS 

Laureate of the French call

Home institution : USA, Cornell University

Project : *CZ-TOP – Water, reactions and isotopes in the Critical Zone*

Host institution : Institut de Physique du Globe, Paris

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Relationships between variations in stream discharge and solute concentrations (C-Q relations) contain information about multiple Critical Zone (CZ) processes, from hydrologic flow paths to weathering reactions to transport time scales. By adding high resolution time series of reactive tracer data (R-isotope ratios of reactive solutes) we will generate C-Q-R data to better understand water movement and reaction in the CZ. By combining recent advances in non-steady state hydrologic modeling, quantitative reactive transport processes, and geochemical tracer data, we can significantly advance our understanding of the combined geochemical and hydrologic processes that generate C-Q-R patterns. Our approach is to treat the Critical Zone as a complex biogeochemical reactor in which fluids and minerals interact as a function of fluid flow path, residence time and reaction. Tracers for weathering reactions such as Ge/Si, $\delta^{30}\text{Si}$, and $\delta^{44}\text{Ca}$ reflect both their mineral sources and equilibrium and kinetic fractionations along their transport path, potentially providing unique constraints on flow paths and time scales. Stream outflow values are the result of a convolution of multiple individual transit times. Working with newly developed infrastructure for high resolution chemical sampling and analysis (CRITEX) we will develop methods for rapid isotope tracer analysis, and integrate new time series for tracer data into reactive transport and non-steady state TTD models. The integrated approach will allow us to interrogate the dynamic subsurface and build a more mechanistically based understanding of the key processes controlling water availability and quality in the Critical Zone.



DEWAR WILLIAM 

Laureate of the French call

Home institution : USA, Florida State University

Project : *CONTACTS – Parameterize energy dissipation in the ocean surface/bottom boundary layers for climate simulations*

Host institution : Institut des Géosciences de l'Environnement, Grenoble

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The Earth's climate evolution and sensitivity to human influences strongly depend on the dynamics of the ocean, which absorbs most of the excess heat and greenhouse gases, redistributes them around the globe, and may eventually flux them back into the atmosphere. Numerical climate simulators now partially resolve ocean 'weather' (spatial scales of ~100km, time scales of a few months, the strongest ocean variability in climate dynamics) and because of that provide better climate forecasts than previous models. The dynamics of mesoscale ocean weather at larger scales is rather well simulated today. In contrast, the interaction of ocean weather with smaller scale flows (scales of ~10km) represents a significant sink of kinetic energy, which is still crudely understood, quantified, and simulated. More importantly, the misrepresentation in ocean models of this small-scale energy sink adversely affects the ocean's full energy spectrum, and hence yields important inconsistencies in ocean-atmosphere models used for climate projections. The CONTACTS project aims to study and parameterize this missing effect where it is critical: within the surface and bottom boundary layers of the ocean, where it interacts with the atmosphere and topography. Our team will gather experts in Geophysical Fluid Dynamics, sub-meso/mesoscale turbulence, and high-resolution global ocean models. The project will contribute to improve such models (in particular NEMO) and climate simulators, to interpret and exploit future observations at very high resolution (SWOT satellite altimeter to be launched in 2021), with foreseen benefits for operational oceanography.



ERVENS BARBARA



Laureate of the French call

Home institution : USA, Cooperative Institute for Environmental Sciences (CIRES, University of Colorado) and National Oceanic and Atmospheric Administration (NOAA)

Project : *MOBIDIC – Modeling biologically-driven processes in clouds*

Host institution : Institut de Chimie, Clermont Ferrand

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The project MOBIDIC (MOdeling Biologically-Driven processes In Clouds) aims at improving the representation of biological processes in clouds. Cloud droplets can be considered media where chemical, physical and biological processes occur. Chemical composition of cloud water affects rain composition which impacts air quality and soil; in addition, evaporating cloud droplets release aerosol particles that – depending on their composition and size – lead to cooling or warming of the atmosphere and to subsequent cloud formation.

While chemical processes in cloud droplets are relatively well studied, the importance of bacteria in converting chemical species in clouds cannot be estimated yet due to the lack of suitable numerical model codes. Laboratory and ambient data (e.g., from the local Puy de Dôme station) on bacteria processes and abundance in clouds will be used to complement current chemical clouds models to assess the importance of biological processes in cloud droplets.

In addition to their role in liquid water clouds, biological particles are known to act as nuclei, on which the formation of ice clouds can occur. We will evaluate available data on ice nucleation activity of various microbiota and categorize them under physical, chemical and/or biological aspects. This approach will lead to identifying trends and to finally develop comprehensive model descriptions of ice cloud formation.

In summary, MODIBIC will result in highly needed tools to the scientific community to predict the role of microbiota in the atmosphere and their subsequent interactions with all compartments of the Earth.



FEDOROV ALEXEY



Laureate of the French call

Home institution : USA, Yale University

Project : *Arctic climate change, global ocean circulation and basin interconnections*

Host institution : Laboratoire d'océanographie et du climat : expérimentations et approches numériques, Paris

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Global climate change is already affecting major elements of the Earth's climate system, but its impacts are especially pronounced in the northern high latitudes. Specifically, a dramatic decline of Arctic sea ice has occurred over the past three decades with the sea ice areal extent decreasing by nearly 30 %. Moreover, permanent sea ice is expected to disappear before the end of this century. The goal of this project is to investigate how this sea ice decline affects global ocean circulation including the Atlantic Meridional Overturning Circulation (AMOC) – the key component of the ocean conveyor that transports heat from low to high latitudes, modulating global and European climates. The project's central hypothesis is that sea ice decline acts to warm and freshen the upper Arctic ocean, generating positive buoyancy anomalies. On multi-decadal timescales, these anomalies spread to the North Atlantic, suppressing deep convection (the sinking of cold surface waters) and thus weakening the AMOC. The resulting changes can modify weather and climate patterns around Europe (e.g. North Atlantic temperatures and the jet stream path) and globally (El Niño and tropical precipitation). A critical question is whether Arctic sea ice decline can accelerate the potential collapse of the AMOC with global warming. Another important question concerns climate links between different ocean basins – for example, the Arctic and the Atlantic, or the Arctic and the Pacific. To study this broad problem, the project invokes a hierarchy of numerical experiments using state-of-the-art climate and ocean general circulation models (GCMs) and comprehensive data and model analyses. The work is conducted at Institut Pierre Simon Laplace (IPSL), the largest climate research institution in France, and is hosted at Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques (LOCEAN).



FORTE ALESSANDRO MARCO



Laureate of the French call

Home institution : USA, University of Florida, Department of Geological Sciences Gainesville, Florida

Project : *Geodynamic perturbations of climate signals (GYPTIS)*

Host institution : France, Institut de Physique du Globe de Paris, Équipe de Géomagnétisme, Paris

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The goal of the GYPTIS project is the mapping of spatio-temporal links between Earth's internal dynamics and climate related signals recorded by surface geological markers. These signals include sea level variations and astronomical (Milankovitch) forcing of paleoclimate variations recorded by stratigraphic data. The sea level data of special interest are high-stands recorded during warm periods, notably Pleistocene interglaciations, the Mid Pliocene Warm Period, and the Paleocene-Eocene transition. Knowledge of sea level during these warm periods provide important clues about the vulnerability of polar ice masses subjected to increased global temperatures. To address these objectives my group carries out computational simulations that track the global-scale movements of hot rocks deep inside the Earth's interior. These calculations reconstruct the evolution of Earth's internal structure over the past 70 million years and the impact on surface elevations of continents, depths of oceans, and changes in Earth's gravity field. These complex whole-Earth simulations are still "work in progress", but the initial results are yielding insights on the origin and amplitude of vertical land movements during the Last Interglacial (125 thousand years ago), directly impacting the interpretation of widely distributed markers of sea level. We also find substantial changes in Earth's global elliptical shape, with major implications for astronomically induced variations of climate.



GUEMAS VIRGINIE



Laureate of the French call

Home institution : Spain, Centro Nacional de supercomputacion

Project : *ASET – Atmosphere-Sea ice Exchanges and Teleconnections*

Host institution : Centre National de Recherches Météorologiques, Toulouse

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Over the last decades, the Arctic sea ice has experienced a drastic decline which is expected to continue in the near-term future. Arctic changes are thought to impact the mid-latitude atmospheric circulation to an extent and through mechanisms which are still highly debated. The inability of state-of-the-art climate models to capture accurately both the rate of Arctic sea ice changes and their impact on lower latitudes is hypothesized to originate from inaccuracies in the representation of atmosphere-sea ice heat exchanges. The ASET project offers to improve the realism of modelled Arctic climate changes and linkages between polar and mid-latitude regions through the development of novel formulations of turbulent heat exchanges between the atmosphere and sea ice. The inadequate formulations currently used for turbulent heat fluxes are mostly due to the lack of available observations in polar regions up-to-date. Within the framework of the Year of Polar Prediction which starts in 2017 and will last until 2019, several observational campaigns are being or will soon be launched in the Arctic and Antarctic. ASET aims at exploiting these new data to develop novel formulations for sensible and latent heat fluxes at the sea ice surface. The impact of these developments will be assessed in historical simulations and in climate change projections. Improving the realism of climate models is an essential step to provide trustworthy climate information to end users. The novel formulations of turbulent heat fluxes to be proposed in ASET could be exploited in the whole fluid mechanics domain.



KIKO RAINER



Laureate of the French call

Home institution : Germany, GEOMAR Helmholtz Centre for Ocean Research Kiel

Project : *Tropical Atlantic Deoxygenation*

Host institution : Laboratoire d'Océanographie, Villefranche sur Mer

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Ocean deoxygenation disrupts marine ecosystems, affects fish stocks and aquaculture and leads to loss of habitat and biodiversity. [Kiel Declaration 2019; Oschlies, [...], Kiko et al.]. Ocean deoxygenation in the recent past was to a large extent caused by global warming, but residual effects might be linked to enhanced oxygen demand in deeper water layers. Ocean deoxygenation affects the highly dynamic upwelling ecosystems of the Eastern Tropical Atlantic (ETA). These ecosystems are regions of intense oceanic productivity and critical for food supply to millions of people. Ocean deoxygenation in these regions might continue due to increased stratification, feedbacks in plankton dynamics, increased respiratory demand and a slowing-down of oxygen supply via the equatorial current system. Establishment of a sustained observation and modelling system for plankton and particle dynamics in the ETA and particularly at the equatorial gateway to the ETA is the major objective of our project. The planned efforts will enable us to elucidate how equatorial current dynamics and biological oxygen demand impact atmospheric carbon uptake, oxygen distribution and available habitat for fish in the ETA. Our work will also establish a basis for a global network of autonomous integrated observation systems on moorings, floats and gliders that will allow a real time assessment of crucial aspects of the global carbon cycle and marine food security.



LUCAS-PICHER PHILIPPE



Laureate of the French call

Home institution : Canada, Université du Québec

Project : *KM-IMPACTS – Analysis of the impacts of climate change using kilometer-scale regional climate models over Europe*

Host institution : Centre national de recherches météorologiques, Toulouse

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With the recent increase in computational power, long 1-3 km grid-mesh Regional Climate Model (RCM) simulations became computationally affordable few years ago. This new generation of RCMs, often called CPRCMs for Convection-Permitting RCMs, has the particularity to resolve explicitly deep convection phenomena, thus removing one of the key uncertainty in nowadays climate simulations. This project will address the improvements of fine-scale high-impact weather events in CPRCM simulations on climate time scales to pave the way to the next generation of climate services. Moreover, a thorough analysis of global climate model (GCM), classic RCM and new CPRCM simulations will be performed to assess the robustness of their climate-change signals. This project will take advantage of the simulations from the CORDEX Flagship Pilot Study Convection and EUCP projects covering a large part of Europe. Additional CPRCM simulations with the AROME model will be performed over two new regions, one covering the Mediterranean Islands and another covering France. One major aspect of this project will consist in the analysis of the changes of fine-scale meteorological phenomena over the Mediterranean Islands in climate change simulations. Through the project, best practices in using regional climate models will also be elaborated. Finally, new CPRCM climate simulations will be exploited in two impact studies. The first one consists in the analysis of the impacts of climate change on floods using improved hourly meteorological variables over Europe. The second impact study will focus on the future evolution of the urban climate of some large European cities using the more realistic simulated meteorological variables over a diurnal cycle.



RICHARDS CHRISTINA 

Laureate of the German call

Home institution : USA, University of South Florida

Project : *Genomics and Epigenomics of Plant Invasion*

Host institution : Eberhard Karls Universität Tübingen

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In the context of climate change, understanding the mechanisms involved in species resilience is a critical issue for maintaining biodiversity and global sustainability. Biological invasions are one of the most important threats to biodiversity, and they have dramatic ecological and economic consequences. To manage current invaders and prevent future invasions it is critical to understand the processes underlying successful biological invasions. For instance, we know that successful invasive species often rapidly evolve and adapt to their novel environments. The precise mechanisms range from genome to plant phenotypes and biotic interactions but are rarely understood. A true understanding of an invasive species requires a global perspective, to compare a species ecology and evolution in the native versus introduced range. In project “Genomics and epigenomics of plant invasion”, we have completed an integrative and cross continental study of the aggressive plant invader Japanese knotweed. This plant species experiences drastic changes in abiotic and biotic environments in its introduced range. To understand the evolutionary processes during this invasion, and its underlying mechanisms, we have assembled a team of German, French, US and Chinese researchers with complementary expertise in invasion biology and ecological genomics. We have completed a global survey of molecular and phenotypic diversity coupled with measures of the abiotic and biotic environments of nearly 200 Japanese knotweed populations spanning the native and invasive ranges. Then, we established common gardens in the native and invasive ranges in order to run experiments, combined with genomic methods to characterize how this globally successful invasive accommodates environmental challenges. Our project is unique in its combination of geographic scale and biological depth. We have established a living resource for future experimental work. Combined, this work will provide important insights about one of the world’s worst invasive species and serve as a model for successful global collaboration.



TANAKA KATSUMASA 

Laureate of the French call

Home institution : Japan, National Institute for Environmental Studies

Project : *Achieving the Paris Agreement Temperature Targets*

Host institution : Laboratoire des Sciences du Climat et de l’Environnement, Gif-sur-Yvette

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The Paris Agreement aims to stabilize the global warming at 2 °C and eventually at 1.5 °C. Many countries, regions, cities, sectors, organization, and individuals are making efforts and commitments to achieve such goals. However, the actual challenges are so gross that the current efforts and near-future commitments do not add up to meet the goals effectively. The present circumstance points to a need to understand the consequence of exceeding 2 °C at least temporarily. This project consists of three studies related to temperature overshoot scenarios. The first study will be based on the scenarios containing temperature overshoot of different durations and magnitudes. It will investigate the underlying emission pathways and other phenomena such as sea-ice extent, ice sheet melting stability, shifts in hydrology, and abrupt ocean circulation changes. The second study will address “learning” of uncertainties as a result of more observations and better understanding in the future. It will explore how the learning might be in the future and how future emission pathways could adapt to such learning. The third study will deal with emission metrics to express non-CO₂ emissions on the common scale of CO₂, a key tool to for the multi-gas policy. It will investigate what metrics are consistent with the Agreement goals including overshoot cases. These three studies will be carried out by means of a compact Integrated Assessment model, compact and full-fledged earth system models, and CMIP6 datasets where applicable. The project will aim to inform the political debate on the choice of future pathways and provide inputs to the Global Stocktake in 2023.



TEIXIDO NURIA



Laureate of the French call

Home institution : USA, Hopkins Marine Station of Stanford University

Project : *4Oceans – Predicting future oceans under climate change*

Host institution : Laboratoire d’Océanographie, Villefranche-sur-Mer

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The increasing concentration of atmospheric CO₂ is driving changes in the ocean’s physical and chemical properties, with important consequences for its ecosystems and the critical services they provide to humans. Projections suggest a sea surface warming of 3.2 °C, a decrease in surface pH of 0.4 units by the end of this century, and an overall increase in environmental variability. The Mediterranean Sea is a hot-spot of global change with a warming sea surface temperature projected to be 20 % higher than global projections and an increase in extreme events such as marine heatwaves. The 4Oceans-Mopga project seeks to investigate marine organisms’ physiological, ecological and adaptive responses to ocean warming and ocean acidification in the Mediterranean Sea. The overall goal of 4Oceans-MOPGA is to advance our understanding of species and ecosystem resilience under present conditions and future climate scenarios. We combine skills in coastal oceanography and carbonate chemistry, marine ecology and biodiversity, physiology, statistical analyses, and molecular tools. One of the major findings is that the Mediterranean Sea experienced a series of marine heatwaves during the period between 2015 and 2019. The study showed that the Levantine and Aegean Seas are the warmest regions and marine heatwaves are becoming common, intensifying rapidly, and extending over larger areas.

These extreme events resulted in mass mortality of 50 species across habitats and depths, including *Posidonia oceanica* meadows or coral assemblages, two of the most emblematic habitats in the Mediterranean. Interestingly and worrying, the Mediterranean Sea was affected by some of the most extreme temperatures with sea surface temperature anomaly of + 1.3 to 2.6 °C recorded along the coast of France during the summer of 2022. Unprecedented marine heatwaves are driving ecological shifts, threatening its ecosystem’s health and functioning of coastal habitats. For biodiversity responses to ocean acidification, we analyzed the ocean chemistry and the coverage of marine species on rocky reefs at natural CO₂ vent systems (where seawater is naturally acidified). These unique sites are used as natural analogues to investigate future ocean acidification conditions. In this study, we are currently analyzing the loss of functional diversity and how this loss is linked to some key processes related to ecosystem functioning under ocean acidification.

For coral tolerance to ocean acidification, we reported unexpected shifts in the skeletal and growth patterns of corals. The first transcriptome assembly for this species was also performed. Moreover, unexpectedly, we witnessed the spawning of the coral *Astroides calicularis* in the field. This allowed us to run experiments on the effects of ocean warming and acidification on the early life stages of this species. Finally, 4Oceans endeavors to do science that can contribute to nature-based solutions, while contributing to protect biodiversity and nature. To this end, we work with marine macrophytes (e.g. seagrasses, macroalgae), which can help to local mitigate ocean acidification by short- (e. g. local modification of pH through net photosynthesis) and long-term (e. g. carbon sequestration) removal of CO₂. For more information see here: <http://4oceansmopga.com>



THOMAS HELMUTH 

Laureate of the German call

Home institution : Canada, Dalhousie University

Project : *The Ocean's Alkalinity : Connecting geological and metabolic processes and time-scales*

Host institution : Helmholtz-Zentrum hereon

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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 of bioenergy to a large extent, which comes with the need to massively employ fertilizers and its consequence: eutrophication and potentially alkalization 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.



VALLA PIERRE



Laureate of the French call

Home institution : Switzerland, Universität Bern

Project : *MAGICLIM – Earth Surface dynamics: mountain glaciers & landscape evolution under a changing climate*

Host institution : Institut des Sciences de la Terre, Grenoble

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A quantitative understanding of landscape sensitivity to (anthropogenic) climate change requires reconstructing environmental records of past climatic variations and the coupled landscape response. The MAGICLIM project has been conducted in the western European Alps and Eastern Pyrenees, two mid-latitude mountain environments, to investigate the interactions between time-evolving climates, paleo-glaciers and mountain erosion. The research strategy has been based on collecting geomorphological and paleo-environmental records in different settings to quantify the dynamics of alpine glaciers and erosion over millennial timescales.

A multi-disciplinary approach was applied with two main research axes : (1) high-resolution spatial and temporal reconstructions of past glacier extents from field mapping, remote sensing and earth-surface geochronology, combined with numerical glacier modeling to assess the climate forcing on paleo-glacier fluctuations, and (2) quantification of (peri-)glacial and post-glacial erosion in alpine settings. A third research direction emerged during the project, linking biodiversity and long-term evolution of alpine ecology with glacier fluctuations and high-altitude mountain erosion. The main scientific challenge has been to apprehend how glacial and geomorphic processes and timescales interact in regulating the landscape response to a changing climate.

Paleo-glacier reconstructions (western French and Italian Alps) first show a strong sensitivity of maximum glacier extents to regional precipitation patterns and their temporal changes related to global/hemispheric atmospheric circulation, rather than following global temperature trends. During the Lateglacial period, the glacier response to glacial/interglacial transition is complex, due to the 3D configuration of alpine watersheds (in terms of moisture sources and catchment hypsometry). Alpine rock glaciers, geomorphic actors being active over the Lateglacial to Holocene times, would provide complementary paleo-climatic information when combined with paleo-glacier reconstructions. In terms of quantification of mountain erosion, a large-scale compilation of millennial catchment-wide erosion rates at the scale of the European Alps provides the first spatial reference to assess functional relationships between topographic relief, past and modern climatic conditions, and erosion dynamics.

These results highlight the glacial imprint on the Alpine topography and the strong relief inheritance of past glaciations on post-glacial erosion rates and patterns in the European Alps. At more local scales, investigations evidenced the influence of litho-tectonic inheritance for both relief configuration and active geomorphic processes, in turn providing high spatial variability in catchment post-glacial erosion rates. Ongoing efforts in the Alps and Pyrenees are targeting sedimentary archives to quantify using geochemical tracers the respective contributions of glacial vs. non-glacial sediment sources in the total sediment budget, during both the Lateglacial and Holocene times. This will ultimately provide a deeper understanding of the physical processes and interrelated mechanisms involved in the Earth Surface dynamics, thus enabling predictive tools to evaluate the Earth Surface response to past, current and future climate change.



WANG CHIEN



Laureate of the French call

Home institution : USA, Massachusetts Institute of Technology

Project : *EUROACE – Enhancing the Understanding of the Roles of Aerosols in Climate and Environment*

Host institution : Laboratoire d'aérodologie, Toulouse

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Project Challenges: Aerosol remains one of the most uncertain factors in projecting climate change. The EUROACE project is to advance our knowledge about the critical while still poorly understood issue of climate impacts of aerosol-cloud interaction, and to innovate new methods to improve the representations of key aerosol-cloud physical processes.

Project Methods: A modeling framework including global, regional, and cloud-scale models will be improved and deployed to study the responses of cloud features, circulation, and precipitation to aerosol variations from abundance to chemical compositions. Observations from field campaigns, satellite, to climate, aerosol and atmospheric chemistry networks will be extensively used to constrain model simulations. The cloud system responses will be simulated with convection-resolving resolution while large domain coverage to resolve aerosol-cloud interaction in sufficient details under various large-scale environments. We will use machine learning and other advanced data science skills as well as a large quantity of results from detailed process models with explicit aerosol and cloud microphysics to derive parameterization to represent aerosol-cloud interaction in global and regional models. We will also experiment using deep learning algorithms alongside observational or reanalysis data to forecast the occurrences of several environmental or weather extreme events ranging from low visibility haze events, hailstorms, to extreme rainfall events. We will share these new schemes and findings with broader research communities.

Project Results: Using a state-of-the-science regional model with interactively coupled chemistry and aerosol module, we have found strong evidence of the rainfall enhancement by fire aerosols over Maritime Continent during the monsoonal transition phase. Another study based on data from a field campaign and an ultra-fine resolution modeling has identified the effect of black carbon aerosols from biomass burning and local pollution on affecting the lifetime of radiatively important low clouds over southern West Africa. Data analysis added by machine learning methods have revealed the significant increase of extreme rainfall events during the Indian summer monsoon seasons in the past 120 years and suggested a potential correlation of such a trend with many anthropogenic influences including urbanization. A further modeling effort has recently indicated that the emissions of air pollutants including aerosols and urban heat island effect accompanying urbanization can significantly modify the distribution and strength of extreme rainfall events over India. The project has also resulted two new schemes to improve the representation of aerosol-cloud interaction in the models, including an aerosol-ice particle microphysics scheme and a rain formation scheme. A deep learning framework has also been developed and trained for several applications including forecasting the occurrence of severe haze events in Singapore, Beijing, Shanghai, and Paris, occurrence of severe hailstorm in South France as well as Corsica, and the extreme rainfall events during the Indian summer monsoon.

Possible Action and Science Policies: The research findings produced by EUROACE could further our knowledge in climate science and be used to educate public. The schemes, models, and trained machines developed in the project could benefit science advancement. The results regarding the weather and environmental impacts of aerosols from different sources can be used to make effective environment protection and emission mitigation policies.



WU HENRY C. 

Laureate of the German call

Home institution : France, Laboratory of Climate and Environmental Sciences

Project : *Witnesses to the Climate Emergency: Ocean acidification crisis and global warming observations from tropical corals (OASIS)*

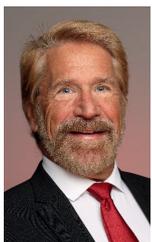
Host institution : Leibniz-Zentrum für Marine Tropenforschung, Bremen

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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 seawater 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.



CANTRELL CHRISTOPHER



Laureate of the French call

Home institution : USA, University Colorado Boulder

Project : *ACROSS – Atmospheric ChemistRy Of the Suburban foreSt*

Host institution : Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil

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Humans have long recognized that their air can become contaminated through natural and non-natural events. The problem became particularly apparent as people moved into large cities where the high population density exacerbated the pollution associated with home heating and industry. Awareness became particularly acute when thousands of people died in a few days from severe episodes.

In recent decades, significant progress has been made understanding the causes and impacts of urban air pollution. Generally, urban air quality has improved through enhanced knowledge and regulatory action. While significant numbers of people still die prematurely each year from air pollution, significant progress has been and continues to be made. Scientific investigation has exposed the processes by which primary pollutants, such as oxides of nitrogen and volatile organic compounds, are transformed in the atmosphere, leading to their oxidation and ultimate removal, while at the same time producing secondary species such as ozone and organic aerosols. Such substances can be toxic for humans, animals, and plants. Similar processes are involved in the processing of emissions from plants and trees but leading to different types and amounts of products.

The ACROSS project is a framework to improve understanding of atmospheric chemical and physical processes that occur when mixtures of urban and rural air masses are processed by the atmosphere. The initial several years of the project involved detailed planning and entrainment of the community in developing measurements sites and platforms for a comprehensive field measurement campaign. The goals of this campaign were, through direct observations of atmospheric composition in urban, suburban, and rural locations, to evaluate whether atmospheric oxidation processes are different in air mass mixtures. For example, does oxidation of volatile organic compounds lead to different products that are more or less prone to uptake into aerosols? Are reactive nitrogen compounds partitioned differently? Do aerosols have different physical and optical properties? Are the amounts of secondary products such as ozone and aerosols modified?

After years of preparation, the field measurement campaign was successfully completed in late July 2022. The next steps involve processing of the data collected during the campaign followed by analysis using statistical methods and comparison with detailed numerical computer models. These analyses are expected to lead to important scientific presentations and publications that could change our view of atmospheric chemistry when cities are located near forests and other areas of rural emissions. These results could change the approaches employed to control air pollution and reduce its impacts.



ESPINOZA JHAN CARLO

Laureate of the French call

Home institution : Peru, Instituto Geofísico del Perú

Project : *AMANECER – Quantify the Amazon-Andes climate connectivity and impacts of climate change in Amazon rainforest*

Host institution : Institut des Géosciences de l'Environnement, Grenoble

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The Amazon is the world's largest river basin and comprises about 40 % of the planet's tropical forests. It plays a key role in the water, energy, and carbon cycles that interact with the global climate system. The Amazon hydrological system now faces great risks due to climate change and increased anthropogenic pressure such as deforestation. These environmental alterations require a better understanding of their potential impacts on the components of the basin's water cycle at different scales.

The main goal of the AMANECER (<https://sites.google.com/view/amanecer-project>) project is to better understand how climate change and regional modification of land cover could affect the water cycle in tropical South America, particularly in the Andes-Amazon transition region. At the heart of AMANECER is the co-construction of projects between South American and French scientists, and the training of students from the Amazon-Andean countries. This project also aims at consolidating a unique Franco-South American research network in the context of the ANDEX-GEWEX (<https://www.gewex.org/project/andex/>) Regional Hydroclimatic Program (RHP).

AMANECER proposed a methodology based on observational and modelling approaches. Using the pattern recognition framework of weather typing significant changes in the meteorological situations related to the lengthening of the dry season in Amazonia and the intensity of the forest fires season were identified. The relationships between changes in the observed components of the water cycle with changes in forest cover during the last 40 years was also analyzed. In the southern Bolivian Amazon, the tendency of decrease in precipitation is systematic, mainly in places where there is a high ratio of deforested areas ($\uparrow 40-50\%$).

The continued deforestation during the last half-century in the Amazon basin threatens the existence of the biggest rainforest in the world. Through the use of high-resolution simulations with the regional climate Weather Research and forecasting (WRF) model and a deforestation scenario of 45 % of cleared Amazon area, we identified strong alterations in the surface energy balance. Our results show a decrease in the moisture transport entering the continent from the Atlantic Ocean, a reduction in moisture convergence and ascending air velocities, and rainfall depletion of about 20 % in the Amazon basin as a consequence of the alterations in the regional surface energy balance. Nighttime precipitation is reduced 20-30 % over the eastern flank of the Andes as the result of weaker moisture transport from the Amazon to the tropical Andes. Deforestation affects also the wet season onset in the southern Amazon. Simulation results with the WRF-ORCHIDEE coupled model suggest the specific weather types linked to the onset and the mature phase of the wet season are delayed in forest loss conditions. Although the interaction of forested and cleared areas is fundamental for the wet season onset, expanding the deforested patches can decrease the triggering of convective activity that only occurs over the moist environment of rainforest areas.

These results from AMANECER will be useful for a starting project called "The 30 x 30 for Nature and People in Peru" (PI JC. Espinoza and I. Palomo – MOPGA/IGE-IRD and M. Montoya WCS-Peru). The overall goal of this research project is to identify the optimal locations for the future establishment of protected areas or other effective area-based conservation mechanisms (OECMs) in Peru considering the multiple targets of biodiversity conservation, climate change mitigation, and water provision. This project is funded by WCS-Peru (<https://peru.wcs.org>) for the period 2023–2025.

The Amazon-Andes hydroclimatic connectivity is an excellent case study for improving our understanding of the coupled dynamics between the water and energy cycles. Reduced uncertainties in future projections of water availability and extreme events is a key topic under the ongoing context of climate change and land use changes in South America. Therefore, results from the AMANECER project will be particularly relevant for starting scientific initiatives at continental scale, such as ANDEX (Co-chairs JC. Espinoza and M Masiokas-IANIGLA, Argentina), an initiating Regional Hydroclimate Project (RHP) of the GEWEX Hydroclimatology Panel (GHP) a central project of the World Climate Research Program (WCRP). ANDEX aims to understand, model and predict the dynamics of the water and energy cycles over the Andes cordillera, at a wide range of temporal and spatial scales, and their linkages with the surrounding oceans, land surface and major river basins, such as the Amazon.



GIANNINI ALESSANDRA 

Laureate of the French call

Home institution : USA, École normale supérieure-PSL and Columbia University

Project : *PRODUCT – Processes of climate change in the tropics*

Host institution : Laboratoire de météorologie dynamique, Paris

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This project sought to advance interdisciplinary understanding of climate change in the Sahel. It sought improved understanding of the physical climate system, in order to predict variation and project change, as well as of its interaction with society, paying particular attention to the issue of the sensitivity of household food security to climatic variation.

We opportunistically undertook the analysis of available multi-model ensembles of climate simulations, whether reproducing the historical past, predicting seasonal to interannual fluctuations or projecting future change, to advance process-based understanding of variability and change in Sahelian precipitation. The analyses carried out not only validated the progress made in model simulation of relevant processes (Giannini et al. 2020, in *Geophys. Res. Lett.*). They also tested the robustness and limitations of an interpretation (Giannini et al. 2013, in *Environ. Res. Lett.*) seeking to establish oceanic influence as the primary driver of Sahel rainfall, regardless of whether the surface temperature of the oceans varies naturally or changes under the influence of human emissions of aerosols and greenhouse gases (Giannini and Kaplan 2019, in *Climatic Change*; Herman et al. 2020, in *Scientific Reports*).

Just as opportunistically, we exploited national-scale household surveys collected by the UN World Food Programme and its in-country government and non-governmental partners in Senegal, the westernmost country in the Sahel facing the Atlantic Ocean. These extensive surveys provide a nuanced characterization of food security and its relation to patterns of food production and consumption, and livelihoods. The repetition of three such surveys in the 2010s allowed us to single out the influence of climate variability, which is clearly discernible when comparing a drought year to normal years. The classification of households based on means of food access and recourse to coping strategies when favored foods are not accessible also allowed us to propose targeted solutions (Ilboudo-Nébié et al. 2021, in *Global Food Security*).

These analyses highlight the structural food insecurity of farmer households (Giannini et al. 2021, in *Frontiers in Climate*). While the demonstrated improved skill in multi-model ensemble systems currently in use in seasonal climate prediction (Giannini et al. 2020, in *Geophys. Res. Lett.*) may provide a potential short-term solution, the persistence of food insecurity for agriculture-based livelihoods opens up the perspective for future research into its global, historical determinants.



HOVEYDA AMIR



Laureate of the French call

Home institution : USA, Boston College

Project : *Multi-Catalyst Systems for Energy Efficient Chemical Synthesis*

Host institution : Institut de Science et d'Ingénierie Supramoléculaire, Strasbourg

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Catalysis can contribute considerably to earth-friendly research and development. We were able to accomplish a number of important goals. Those summarized below are likely the most important.

1. Click reactions link two fragments under mild conditions and are indispensable to progress chemistry and medicine. Catalytic click variants involve robust functional units made to react controllably. The wide appeal of click is largely due to the stunning success of copper-catalyzed azide-alkyne cycloaddition (CuAAC). The more recently introduced base-catalyzed sulfur-fluoride exchange (SuFEx), which is orthogonal to CuAAC, has shown promise. It would be particularly desirable that click-generated linkages are alterable and differentiable, rendering subsequent selective diversification feasible. Nonetheless, linking rings formed by CuAAC cannot be modified and changeable SuFEx connectors are non-differentiable. To address this important limitations, two click-and-modify strategies that entail the merger of four readily available and cheap chemicals, namely, a nitrile, a monosubstituted allene, a diborane, and a hydrazine or an aniline. The transformations are easy to perform, delivering robust yet selectively modifiable and fluorescent hubs. They are orthogonal to CuAAC and SuFEx and we have been able to highlight their enormous potential in materials research and drug development by facile syntheses of sequence-defined branched hexa- and heptadecamers, a site-selectively modifiable polymer, two cilengitide-derived drug conjugates and a pentagastrin-derived two-drug conjugate.

2. A molecule's contour is key to its ability to elicit biological response, which is why it is important that it can be altered precisely. However, a natural product's framework can be modified only if it is available in sufficient quantities; many are not. Even then, many structural adjustments are often made simultaneously, increasing the likelihood that a hit goes undetected. We have designed a programmable strategy for accessing bridged polycyclic amine scaffolds marked by precise skeletal adjustments. Central to the approach is a bespoke catalytic multicomponent process, designed to furnish, progressively and divergently multifunctional hubs that can, precisely and controllably, be used not only to generate a natural indole alkaloid but also a collection of one- or two-methylene expanded, contracted, and/or distorted frameworks (steps/scaffold efficiency = 7; steps/analog efficiency = 4). In vitro testing shows that insertion of a methylene in two particular sites affords a skeleton that, unlike the weakly anti-malarial natural product and its other analogs, is cytotoxic against all four cancer cell lines screened (IC₅₀ as low as 3 μM). Docking studies (2198 protein targets) reveal that, while precise re-modelling impacts binding affinity considerably, no particular scaffold is privileged. Molecular dynamics shed light on how a specific alteration influence interaction with a receptor.

Through these studies, we illustrate that catalytic processes specifically designed to generate modifiable hubs that facilitate access to surgically altered scaffolds, can be of notable utility in drug development.



KAPLAN JED 

Laureate of the German call

Home institution : Switzerland, University of Lausanne

Project : *Feedbacks between land cover, people, and climate in the seasonally arid tropics (MONSOON)*

Host institution : Universität Augsburg

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Possibly more than anywhere else on the planet, the seasonally arid tropics of Africa and South Asia are critical for understanding the feedbacks between climate and society in the future. Home to nearly a quarter of the world's population and experiencing faster demographic growth than anywhere else on the planet, these regions are currently undergoing rapid landscape changes caused by deforestation, agriculture, and urbanization. At the same time, fossil fuel consumption and other industrial activities that affect climate globally are leading to increases in the frequency of extreme climate events in these regions, including drought and heat waves. In Africa and South Asia, local weather and climate is strongly influenced by land cover. This means that human activities such as deforestation, irrigation, and urbanization could exacerbate the effects of global climate change. Africa and South Asia are thus at a nexus for global change, where climate combined with land use and land cover may determine the future habitability of landscapes and the success or failure of societies to adapt to climate change. Parts of these regions are already affected by water and therefore food insecurity; reductions in rainfall caused by global climate trends and exacerbated by regional land use and land cover change in the future could lead to conflict, migrations, and social instability. At the same time, increases in the frequency of climate extremes such as heatwaves, wildfire, and dust storms, also potentially exacerbated by land use, could cause large regions to become at least seasonally uninhabitable, and provoke the spread of diseases that affect humans and their animals. For these reasons, it is essential that we have a good understanding of both climate and land cover change in the seasonally arid tropics.

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.



LAUVAUX THOMAS



Laureate of the French call

Home institution : USA, Pennsylvania State University

Project : *CIUDAD – Quantification of urban greenhouse gas emissions*

Host institution : Laboratoire des sciences du climat et de l'environnement, Saclay

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Urban emissions of Greenhouse Gases (GHG) represent currently about 70 % of the global emissions and could increase rapidly as large metropolitan areas are projected to grow twice as fast as the world population in the coming 15 years. Monitoring these emissions will require the use of independent approaches to implement transparent regulation policies. The deployment of atmospheric GHG sensors across few metropolitan areas combined with meteorological models offers a unique solution to quantify GHG emissions rapidly and at high resolutions.

Building upon existing measurement networks and satellite missions, the CIUDAD project will construct an adaptive assimilation system able to produce GHG emissions for each sector of the economy over multiple cities. The project will focus on Paris, Mexico City, Indianapolis and Los Angeles, four urban environments with varied economies and demographics. The first objective of the project is to quantify urban GHG emissions by utilizing atmospheric GHG data and aerosols with socio-economic information into a single data assimilation system. In the second objective, we propose to advance significantly the capability of current assimilations systems by implementing the next generation of meteorological models for urban applications.

Our novel approach will use an Adaptive Mesh Refinement atmospheric model to simulate GHG mixing ratios over the entire globe at coarse resolution (few degrees) while zooming on specific cities at high resolution (about 1km) without any discontinuities in the atmospheric flow. The adaptive system will integrate urban deployments into broader observing networks to produce national-scale GHG emission assessments.



LEE CAROL EUNMI



Laureate of the French call

Home institution : USA, University of Wisconsin, Madison

Project : *Rapid Evolutionary Responses to Climate Change*

Host institution : Marine Biodiversity Exploitation and Conservation (MARBEC),
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Climate change threatens biodiversity and ecosystem integrity of the oceans. In particular, salinity is declining rapidly and dramatically in many high latitude coastal regions due to increased precipitation and ice melt, while temperatures are rising. Such coupled changes will likely have severe detrimental impacts on organismal physiology, population growth, and production. Evolutionary responses are critical to avoid extinction when environmental stressors exceed physiological thresholds. However, no study has explored evolutionary responses to the combined effects of salinity and temperature. Thus, the goal here is to address the questions: (1) To what extent could populations evolve in response to changes in salinity, temperature, and their interactions? (2) How will physiological limits and evolutionary potential of populations impact range shifts and future probabilities of local extinctions? We will address these questions by exploring (1) physiological limits of wild populations, (2) constraints on physiological evolution in laboratory selection experiments, and (3) future range shifts and probability of extinctions in response to climate change, by including data on physiological limits (#1) and evolutionary potential (#2) into mechanistic models. Evolutionary information is necessary to make climate change models predictive. This study is transformative in injecting evolutionary data into predictive models of climate change impacts, in order to make accurate predictions on limits to future range shifts and probability of extinctions. Such insights are critical for projecting the future sustainability of ecosystem integrity of the planet.



PALOMO IGNACIO



Laureate of the French call

Home institution : Spain, Basque Centre for Climate Change

Project : *Pathways for Transformation in the Alps (PORTAL)*

Host institution : Institute of Environmental Geosciences (IGE), CNRS, France

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As recent IPCC and IPBES reports have shown, there is a fundamental need for delivering transformative change to achieve environmental and social targets as those in the Sustainable Development Goals. The PORTAL project, Pathways for transformation in the Alps, focuses on the potential of using nature to deliver transformative change and create just and sustainable societies. To do so, it analyses nature-based solutions, which are the actions that protect, restore or sustainably manage nature in order to provide benefits for people and nature.

Our analysis of 93 nature-based solutions in mountains globally identified empirical cases of transformative change. These transformative nature-based solutions have tackled land degradation, biodiversity loss, climate change and poverty, which highlights the multifunctionality of nature-based solutions. The process of nature-based transformation is as much nature-based as people-based, as these nature-based solutions are based on a strong stakeholder engagement, different nature-values and knowledge types, and nature management practices like restoration.

Within PORTAL, we have created a database of nature-based solutions for climate change adaptation in the Alps. Our analysis shows that nature-based solutions are in general not located in areas that experience higher climate change impacts, such as floods, droughts, rockfall and heatwaves. Moreover, nature-based solutions are not located in areas that present a deficit for ecosystem services that would allow to better adapt to these climate change related hazards. Fine scale mapping of land use changes occurred through nature-based solutions implementation will allow us to evaluate improvements in biodiversity and a series of ecosystem services that nature-based solutions provide, as well as to assess if these ecosystem services are provided equitably. Our spatial analysis will also help to identify optimal areas for the implementation of nature-based solutions towards objectives of biodiversity conservation and climate change mitigation and adaptation.

Our analysis of policy documents of landscape planning shows that nature-based solutions are usually broadly considered, but that specific actions linked to economic incentives are scarce. Through interviews and questionnaires, we have found that valuing nature and awareness of climate change play an important role in the implementation of nature-based solutions, but that knowledge co-production across different stakeholder typologies is still limited to a minority of examples.

Further economic support, as well as stronger stakeholder engagement, seem fundamental for large-scale implementation of nature-based solutions to achieve different environmental and social targets. Moreover, a macro-regional strategy for the future implementation of nature-based solutions in the alps could facilitate a better spatial location regarding future climate change risks.



PARMESAN CAMILLE



Laureate of the French call

Home institution : USA, University of Texas – UK, University of Plymouth

Project : *CCISS – Climate Change Impacts on Species*

Host institution : Station d'écologie théorique et expérimentale, Moulis

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More than a decade has passed since it became clear that anthropogenic warming was driving observed changes in wild species. My group's recent work has concentrated on improving understanding and future projections of responses to climate change by wild species in their timing and their geographic ranges. My strength is in linking impacts of climatic trends and extreme climate events on ecological, evolutionary and behavioral processes at the population level to patterns of biodiversity change at the global level. I will continue this research into two new areas: (a) Impacts of societal importance: changes in human disease risk as a consequence of range shifts of disease organisms, their wild vectors and reservoirs; (b) Impacts in high-risk habitats: assessing climate change risks for species inhabiting montane and boreal regions, under-studied but vulnerable systems.

Tackling impacts of global climate change at the population level also provides an appropriate platform for exploring uncertainty in future impacts, and incorporating that uncertainty into conservation planning for the coming century. I will use techniques from economic modeling to incorporate Robust Decision-Making (RDM) theory into conservation planning. RDM uses scenario modeling to provide a range of possible futures that accommodate uncertainties in what the future climate may be and how species may respond. RDM algorithms then allow us to select actions that could be taken now that lead to the highest probability of a positive outcome across all possible futures. Such an action is, then, "robust" to those uncertainties.



POSSNER ANNA



Laureate of the German call

Home institution : USA, Carnegie Institution for Science

Project : *Organisation and Cloud-Radiative Properties of Low-Level Mixed-Phase*

Host institution : Goethe-Universität Frankfurt/Main

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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 kilometers 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.



RENARD DELPHINE 

Laureate of the French call

Home institution : USA, University of California

Project : *ASSET – AgrobiodiverSity for a food-Secure planET*

Host institution : Centre d'écologie fonctionnelle et évolutive, Montpellier

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Ensuring food security under a changing climate is among societies greatest challenges. Rising temperatures, heat waves and droughts have caused crop failures, reduced potential yields, and driven instability in global food markets. Climatic projections suggest that these impacts and their associated human costs of poverty, malnutrition, and political unrest will worsen. Research on solutions to develop robust food systems is therefore urgently needed.

ASSET will evaluate the potential effectiveness of a novel agrobiodiversity-based strategy. Evidence suggests that increased agrobiodiversity reduces climatic risks to food production, but how to leverage such benefits remains largely unknown. ASSET will fill this critical gap by providing regionally-specific knowledge on (1) the spatial scale(s), (2) the combinations of crops, and (3) the existing practices adopted by farmers that promote the yield stabilizing effect of agrobiodiversity against climatic variability. We will combine statistical analyses of existing long-term datasets across Europe, the Mediterranean and Sub-Saharan Africa with mathematical simulations and ethnobiological fieldwork in three case studies (France, Morocco and Senegal).

By placing farmers at the center of our approach, ASSET will yield transformational insights into the design and implementation of diversified agricultural systems that provide agronomic benefits while being feasible for and desirable to farmers. ASSET will thus help strengthen societies capacities to face climate change, contributing to meeting the objectives of the Paris COP 21, implementing multiple Sustainable Development Goals, and ensuring a food-secure future for all.



RIDDE VALÉRY 

Laureate of the French call

Home institution : Canada, Université de Montréal

Project : *CLIMHB – Climate Change, Migrations and Health Systems Resilience in Haïti and Bangladesh*

Host institution : Centre population et développement, Paris

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Migrations have reached globally an unprecedented scale and represent major challenges for societies and health systems to guarantee access to healthcare of the most vulnerable. Climate change, by increasing the intensity of natural disasters and catalyzing environmental degradation, leads to questioning the nature and extent of these ongoing mobility trends. It is the case in Bangladesh and in Haiti where, respectively, 400 000 and 100 000 people move every year from rural areas towards their respective capitals (Dhaka and Port-au-Prince). The capacity of health systems to meet the health needs of displaced persons in their country of origin, or 'climate refugees' in the countries where they migrate temporally or definitely, has so far not received much attention from research. Neither have the resilience and the capacity of adaptation of health systems and professionals in relation to increased migrations. Also lacking is research on migrant strategies to access healthcare services. Empirical studies will be conducted using mixed methods in Haiti and Bangladesh to better understand links between climate change, migrations and health system. Deliberative workshops will be organised and notes of policies will be broadcast to decision-makers and representatives of civil and international organisations (IOM, PAHO, WHO). It will be for IRD to collaborate with researchers of Bangladesh and Haiti, to integrate several disciplinary fields (Health, Migration and Climate Change Studies) and various institutions in France and abroad (Germany, Canada, USA).



SANDERSON BENJAMIN



Laureate of the French call

Home institution : USA, National Center for Atmospheric Research

Project : *RISCCi – Risks and Uncertainties under Climate Change*

Host institution : Laboratoire Climat, Environnement, Couplage et Incertitudes, Toulouse

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A comprehensive climate risk exposure exercise is proposed to assess fundamental uncertainties in model parameterization, with a focus on impacts in central Europe, and for a set of societally relevant climatic hazards (urban heatwaves, flooding, drought, wildfire & crop failure). The core of the project will involve a parameter perturbation exercise for the CNRM-CM6 climate model, with a series of idealized experiments to isolate key parameters in the land and atmospheric components which are critical for controlling the extent of societally relevant impacts under climate change. A surrogate model emulator will be constructed to model performance metrics and model response to greenhouse gas forcing as a function of model parameters. An optimization suite will be used to propose plausible model configurations which represent a range of climate feedback strengths and future impact intensity. These idealized experiments will then be used to inform a fully coupled ensemble of perturbed climate simulations which will be made available to the wider climate community for impacts analysis. Coupled historical and future simulations will represent uncertainty in a range of societal impacts. For example, model configurations will be constructed which minimize and maximize respectively the risk of urban flooding. The PI will then work with impacts experts within CERFACS and CNRS (and externally where necessary) to produce targeted risk assessments in the context of model uncertainty for a number of key impacts which might influence France and central Europe under climate change. All code and simulations will be made available to the community.



SAVOLAINEN VINCENT



Laureate of the French call

Home institution : UK, Imperial College London

Project : *The evolution of stress tolerance in palms*

Host institution : Diversité-Adaptation-DEveloppement des plantes (DIADE), Montpellier

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The project builds on Savolainen's decade-long evolutionary research on the plants of Lord Howe Island, Australia. Uniquely, Savolainen has identified a pair of sister palm species that have speciated on the minute LHI by adapting to different soil types. One of the species, *Howea forsteriana* (the kentia palm), evolved on calcareous soils deposited by the sea, which cause multiple stresses (water, salt and metals), likely affecting flowering time. The *Howea* palms of Lord Howe Island represent an invaluable system to disentangle how plants in general, and palms in particular, have evolved to cope with environmental stresses, and how soil chemistry and microbes can drive speciation. Firstly, we propose to test the hypothesis that speciation can be driven by a few genes that are related to stress tolerance (salt, drought, various metals, high pH, etc), mycorrhizae interactions and flowering time, and that these genes are found in a few genomic islands. Secondly, although we take a comparative palm genomic approach, we will validate gene function in tractable model systems. We will use knockout mutants of homologous genes of interest in *Arabidopsis* and *Brachypodium* grasses, in which we will conduct phenotype rescue experiments using palm genes. Thirdly, using large field experiments in Ivory Coast, we propose to document the role of mycorrhizae and test genes involved in stress tolerance. Finally, all the resources will be assembled and made available in a Palm Comparomics Hub. Hence, our research will lay the foundation upon which selection and transformation programmes can then improve resilience of crop palms to future climatic changes.



SCHEER CLEMENS



Laureate of the German call

Home institution : Australia, Queensland University of Technology

Project : *Climate change, reactive nitrogen, denitrification and N₂O: identifying sustainable solutions for the globe.*

Host institution : Karlsruher Institut für Technologie (KIT)

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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 to which degrees this process will take place. There is substantial interest in mitigating N₂O emissions from agriculture activities as a part of the strategy to combat global climate change, yet methods for estimating N₂O emissions from agricultural sources remain highly uncertain. As Nr use and N₂O emissions are strongly correlated, there is a high risk that the needed intensification of crop production for feeding a growing and hungry planet, might also result in further increases of greenhouse gas (GHG) emissions from global agriculture.

This project used state of the art process-based crop and ecosystem model approaches to assess the trade-off between crop productivity, N fertilizer use, and GHG emissions of agricultural ecosystems. It revised the global budget of terrestrial denitrification and introduced a global database and monitoring framework for soil N₂O emissions providing a reliable basis for national programs to reduce Nr losses and mitigate the climate footprint of agriculture. The potential of residue management to increase soil organic carbon stocks under conditions of climate change from arable soils in the EU was assessed and different mitigation strategies identified. Further it showed how global N losses from cereal production can be minimized, allowing production to be increased without increasing yield-scaled Nr losses. The results demonstrate that by reallocating N fertilizer on current cropland the expected global grain demand for 2030 can be met without increasing the area of arable land while achieving emission targets compatible with limiting global warming to 1.5 degrees C.

Overall, the project provided a detailed assessment of N₂O emissions from cropping systems at different scales and could identify regional emission hot spots promising for most efficient GHG mitigation activities. The modelling framework is now available to policy makers as a tool for better GHG accounting, and can be used to develop and test climate-smart management strategies in specific cropping systems to minimize their contribution to global N pollution and climate change.



SUBRAMANIAN RAMACHANDRAN



Laureate of the French call

Home institution : USA, Carnegie Mellon University

Project : *MAQGA – Make Air Quality Great Again*

Host institution : Observatoires des Sciences de l'Univers Enveloppes Fluides de la Ville à l'Exobiologie (OSU-EFLUVE)/Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil
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WHO estimates that outdoor air pollution causes about 4 million premature deaths worldwide. Developed megacities like Paris still experience severe pollution episodes. But operational networks in Europe do not yet measure air quality at neighborhood level, necessary to accurately assess population exposure. Most Sub-Saharan African (SSA) countries do not monitor air quality, despite heavy pollution from dust, open biomass burning, and residential biofuel use. With industrialization, pollution will worsen unless SSA countries choose sustainable development paths incorporating air quality impacts. Low-cost gas and PM sensors can lower capital costs by 95 % compared to traditional monitors, with acceptable performance and lower maintenance.

This enables unprecedented high spatial resolution monitoring in megacities and basic coverage in low-income countries. We propose the following objectives: 1. Bridge the gap from urban background air quality to population exposure in Western Europe by deploying Real-time Affordable Multi-Pollutant (RAMP) low-cost sensors at high spatial resolution. 2. Expand the RAMP monitor's capabilities further by developing new sensors for VOCs and climate impacting absorbing aerosol. 3. Develop a general calibration framework for RAMP sensors over various outdoor environments in Europe and Africa, and an exploratory assessment for indoor air. 4. Expand existing monitoring networks in Africa using RAMP sensors for a first assessment of specific air pollution sources and help build local capacity. 5. Use RAMP observations for evaluation of high-resolution air quality models and estimates of surface pollution from satellite retrievals.



TESCHE MATTHIAS 

Laureate of the German call

Home institution : UK, University of Hertfordshire

Project : *Particles in Aerosol Cloud Interactions : Stratification, CCN/INP concentrations, and Cloud Lifecycle (PACIFIC)*

Host institution : Universität Leipzig

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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 brightness, development, phase, lifetime, and rain rate of clouds. Even though these aerosol-cloud interactions (ACI) and the resulting climate effects have been in the focus of atmospheric research for several decades, the underlying mechanisms and their role in climate change are still understood only with medium confidence. This lack of understanding can be traced back to (i) the involved processes happening on different time scales and (ii) the challenge of extracting adequate information from an ocean of data.

PACIFIC addresses the second problem by improving the information on both the aerosols and the clouds for ACI studies that are based on satellite observations. On the one hand, we have developed a method to obtain the height-resolved concentration of CCN from spaceborne lidar measurements that provides reasonable values when evaluated with independent measurements. This marks a step change from using inadequate and column-integrated CCN proxies and paves the way towards the first global 3d climatology of CCN concentrations for observation-based ACI studies and as reference for modelling efforts. The method will be refined further to also infer INP concentrations and obtain the respective climatological information. On the other hand, we have moved from considering only snap-shots of clouds in polar-orbiting satellite observations to studying individual clouds in time-resolved observations from geostationary satellites.

We have developed a cloud-tracking methodology that allows to study the evolution of clouds in different regimes throughout their full life cycle. The method can also be applied to modelled cloud fields to assess the performance of cloud-resolving models. Finally, we have developed a tool for matching cloud trajectories with height-resolved satellite observations to combine the novel aerosol and cloud information in a new approach the satellite-based ACI studies. Rather than considering aerosol and cloud properties in coarse grid-boxes, we relate the properties of individual clouds to their surrounding CCN and INP concentrations. Ultimately, the combination of better characterised clouds and quantitative information on the concentration of cloud-relevant aerosol particles at cloud level is expected reduce some of the uncertainty related to ACI effects on climate.



VADEZ VINCENT



Laureate of the French call

Home institution : India, International Crop Research Institute for the Semi-Arid Tropics

Project : *ICARUS – Improve Crops in Arid Regions and future climates*

Host institution : Laboratoire Diversité – Adaptation – Développement, Montpellier

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Farming in dry areas like the Sahel is extremely risky because of water limitation. Climate change will only accentuate this constraint. This undermines food security in the region and impedes its economic rural development, which in turn feeds discontent and become a security issue for the region and neighbour Europe. It is then urgent to find solutions to make agriculture safer and more resilient so that it becomes a driver of development.

Pearl millet and sorghum – the food subsistence basis of dry sub-Saharan Africa – are the target of this research. Harvests fail in hot and dry conditions because the evaporative demand creates an atmospheric moisture stress for the plant. Genotypes adapted to these conditions exist and are those capable of controlling water losses under high evaporative demand. The hypothesis of this work is that hydraulic restrictions in the plant, possibly at the root system level, limit water movement under high evaporative demand and therefore contribute to saving water and making these genotypes more tolerant to water stress. Through an approach integrating physiology, molecular biology, genetics and modeling, we will decipher the mechanisms underlying tolerance, and find the genetic basis of these traits and of plant architecture traits that allow to optimize light capture per unit of water loss. By modeling, we will classify the stress scenarios of the Sahel and predict for each of these scenarios the genetic variants harboring water saving traits that are the most likely to succeed in each agroecological zone. The end products of the project are therefore a better understanding of the mechanisms of tolerance, the knowledge of the genomic regions responsible for tolerance traits, and a predictive knowledge of their effects in different agro-ecological zones. These results will guide and feed the crop improvement programs of our regional partners and those of the CGIAR, with which I am closely linked.



VINCENT EMMANUEL



Laureate of the French call

Home institution : UK, Factama Ltd

Project : *Web platforms influence on climate information*

Host institution : Medialab, Paris

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Most of the public's access to online information is now made via search engines, video platforms and social media. These platforms have come under heavy criticism over the past few years for their participation to the circulation of misinformation and "fake news" to a broad audience. Several platforms have announced taking steps to increase the integrity of information and fight disinformation campaigns. But there is little data available to track the efficiency of these measures and the impact they (will) have on information sharing, public access to information and attitudes. This research project will investigate the extent to which the practices and algorithms of web platforms contribute to shaping the public's access to climate information and their attitudes towards climate change. We propose to develop methodologies to monitor and document the effects of algorithmic personalization and the temporal changes introduced by platforms to their recommendation engines. This will allow us to study how results to frequent climate queries are changing over time, and the extent to which personalization contribute to enclose people in "information bubbles". Finally we will design experimental protocols to investigate how changes in access to climate information on platforms are able to influence public understanding of climate change and attitude towards climate policies.



CARRIER MARION



Laureate of the French call

Home institution : UK, Aston University

Project : *PYROKINE – Fast pyrolysis of waste biomass: Dual kinetics*

Host institution : Université de Toulouse

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Among renewable energy sources, plant biomass can be effectively transformed into energy through adequate thermochemical processes. One of the main challenges is to efficiently control the thermal conversion of heterogeneous materials that possess many chemical and texture functionalities. To obtain reliable kinetic predictions of the complex thermal transformations, a chemical “lumping” method accounting for the complexity of the reactant structures and the multiplicity of parallel and consecutive reactions has been used. This new model simulates major primary chemical reactions occurring in the molten phase and major secondary reactions; thus, predicting the yield of pyrolysis products with a certain degree of confidence. Errors related to the limitations of mass and heat transfer were both detected and adequately removed by considering the ‘true’ temperature-time profile during heating and residence time distribution. Then robust chemical kinetic datasets were obtained resulting in excellent kinetic predictions and revealing the presence of secondary radical reactions characterized by the negative values of effective activation energy at the end of the reaction. When it came to choose the mathematical model for chemical kinetics, the Distributed Activation Energy Model (DAEM), a distributed reactivity model mathematically transcribed into double integral functions, was chosen. To avoid significant numerical complications and therefore approximated results by using numerical approaches, a stochastic method of resolution was used. To do this, a new concept of null-reaction inspired from null-event Monte Carlo algorithms using an integral formulation has been introduced. The DAEM was solved without approximations opening up new solving computation capacities. Further work to use contaminated biomasses as alternatives feedstocks to agricultural and forest residues is currently conducted. Thermodynamics and kinetics are combined to better apprehend the multiphasic nature of the process.



CHOI HEECHAE



Laureate of the German call

Home institution : South Korea, Korea Institute of Science and Technology

Project : *Amorphous-crystal junction: a new class of photochemical semiconductor with high activity and cost-effectiveness*

Host institution : Universität zu Köln

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This project is aiming at developing a new class of semiconductor system, amorphous-crystal junction, to fabricate highly active photocatalysts for clean hydrogen energy and air/water purifications with lowest cost. In electronic devices and electrochemical applications, charge carrier separable functionality of semiconductors is widely utilized. Conventionally used p-n junction and heterojunction semiconductors must be fabricated via expensive and complicated processes, and hence, many factors such as dopant selections, precursors, and CVD conditions must be considered. Therefore, solar energy harvesting technology to produce clean hydrogen energy has been regarded just as a dream world technology. Many researchers in this field have started closing the possibility to use this technology for practical uses, due to many limiting factors: high cost of photocatalytic materials and very limited number of choosable semiconductor materials.

In this project, I suggest a breakthrough idea to solve the problem: amorphous-crystal junction of semiconductors can be utilized as good alternatives of many of p-n junctioned and heterojunctioned. When a semiconductor 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.

My research idea can make breaking solutions for practical and cheap hydrogen energy production, due to following reasons:

1. This approach vastly broadens the choice of materials – No need for dopants
2. Enormously lowered production costs – less heat-treatment



CHRISTOFORIDIS KONSTANTINOS

Laureate of the French call

Home institution : Greece, Democritus University of Thrace

Project : *SUNCO₂H₂EN – Multifunctional materials for a) combined CO₂ capture and conversion and b) H₂ production from H₂O*

Host institution : Institut de Chimie et Procédés pour l'Energie, l'Environnement et la Santé, Strasbourg
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CO₂ levels in the atmosphere have been stabilized over the last years to the highest levels ever detected, contributing significantly in global warming. The increased CO₂ levels are mostly attributed to the current global energy usage. Therefore, we must review our future energy outlook. In this direction, due to our late response to global warming, closing the anthropogenic carbon cycle is an unavoidable step. This can be done via two pathways: a) carbon capture, utilization and storage (CCUS); b) utilization of clean fuels with zero CO₂ contribution during production and combustion. In the second approach, H₂ can be considered the ideal fuel since it has no carbon footprint. The present project suggests an integrated approach to reduce CO₂ levels through the coupling of processes with immediate and long-term impact on global warming.

This will be done through the synergy of i) CO₂ capture and conversion and iii) H₂ production. The first approach will have a direct impact on CO₂ levels while the second will reduce gradually and maintain the CO₂ in acceptable levels. CO₂ capture and conversion will be performed in a single process allowing process intensification and improvement in the overall economics. This will be done by developing multi-component, dual-purpose advanced materials based on composites, where each part will play a different role (adsorption/conversion). H₂ production will be performed through water splitting. Photocatalysis will be used for CO₂ conversion and H₂ production without the need of any external energy input. The combined study under a single project will provide critical information for optimizing materials towards the specific application.



COJOCARU LUDMILA



Laureate of the French call

Home institution : Germany, Institute of Sustainable Systems Engineering

Project : *ECS – Hybrid systems integrating perovskite solar cells and supercapacitors based on coconut activated carbon for Energy Conversion-Storage devices*

Host institution : Institute of Molecular Sciences, The University of Bordeaux

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The continuous increase in energy demand and carbon emissions has raised the urgency of changing to renewable energy sources. Among the renewable energies available, photovoltaics, which directly converts solar light into electricity, is one of the attractive methods to harvest solar energy, the most abundant and available energy source on earth. One of the main limitations of solar cells as a reliable and stable source of power is the fluctuation of the Solar Sun irradiation due to the cycle of day and night. A combination of solar cells with energy storage devices may be a solution to this problem because of the concomitant electricity storage. In the present available photovoltaic-storage systems, the solar panels are externally connected to batteries through wires. Such systems are devoted to storing more energy that can be used overlong time. However, there are many cases where we need to store less energy in an efficient way with minimum energy losses. Furthermore, it is obvious that the future tendency towards volume minimization, low cost, sustainable manufacturing, and executing two or more functions to a single device. In such a case, one of the ideal solution is a supercapacitor connected to the solar cells. In this context, this project aims at designing, processing, and characterizing the performances of integrated devices combining perovskite solar cells and supercapacitors connected through a common electrode based on activated carbon.

Furthermore, along with the fabrication of high-quality perovskite solar cells, this project aims to use activated carbon produced from a renewable resource, more precisely coconut shells, for the electrodes of the supercapacitor and the perovskite solar cell. The advantage of the integration of both types of devices relies on the simultaneous use of a carbon layer as a common electrode for the supercapacitor and counter-electrode and/or hole transport layer for the perovskite solar cell, resulting in an efficient compact device with minimum energy losses. As a first step, we have developed an effective method, using environmentally friendly materials, to obtain carbon materials from coconut shell waste. According to LCA analysis, the CO₂ emissions could be significantly decreased by careful selection of the materials and careful control of the activation process. The production process is considered, therefore «green» since, on the one hand, the low emissions are absorbed by the plants and are then reused to produce the coconut, on the other hand, the use of biomass allows to save natural sources of activated carbons, which are usually extracted from fossil fuels. Among the samples prepared, the activated carbon showing a high surface area in contact with a non-aqueous electrolyte displayed an outstanding storage capability. Integration of this supercapacitor with a carbon-perovskite solar cell in a compact system was possible. Interestingly, as a separate device, the system was able to maintain high overall peak efficiencies at high areal discharging currents compared to other types of solar cell technologies. These results evidence the potential of our integrated perovskite solar cells-supercapacitors system to be used for electronic applications.



GIAMBASTIANI GIULIANO



Laureate of the French call

Home institution : Italy, Institute of Chemistry of OrganoMetallic Compounds of CNR

Project : *TRAINER – Catalysts for Transition to Renewable Energy Future*

Host institution : Institut de Chimie et Procédés pour l'Énergie, l'Environnement et la Santé, Strasbourg

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The project core moves from the preparation of tailored 1D-3D carbon networks to be employed as non-innocent platforms for the bottom-up synthesis of targeted metal and metal-free catalytic materials. Selected C-matrices with mesoporous structures and featuring with specific templating (chemical and morphological) microenvironments will be used for the controlled anchoring, growth and stabilization of single-atom or metal sub-nanoclusters as well as for the ultra-thin surface coating with defective or highly strained (exfoliated) metal-sulfide structures. Surface engineered C-based materials will be also considered as single-phase, metal-free systems for the effective activation and conversion of small molecules in processes at the heart of renewable energy technology. With its catalyst technology, TRAINER prompts the transition towards a sustainable catalysis era by addressing scientifically ambitious but technologically concrete breakthroughs.

It will focus on the intensification of three highly energy-demanding processes, ensuring mild operative conditions and zero or negative CO₂ impact all over the whole production chain. Its catalyst technology will be mainly applied to: 1) H₂ production from water electrolysis (hydrogen-evolution reaction, HER), 2) Hydrocarbon production from hydrodeoxygenation (HDO) of oxygen-rich biomasses, 3) Production of chemicals and energy vectors from CO₂ electro-reduction. Other satellite processes will complete the study, strengthening the impact and long-term vision of the proposal. Advanced characterization techniques (including operando studies) will give insight on the catalysts properties during all their operative life. An overview on the project activity and its main achievements are available on the TRAINER official web-site (<https://www.trainermopga.com>)



GOLDTHAU ANDREAS 

Laureate of the German call

Home institution : UK, Royal Holloway, University of London

Project : *Investigating the systemic impacts of the global energy transition (ISIGET)*

Host institution : Institute for Advanced Sustainability Studies (IASS), Potsdam; Willy Brandt School of Public Policy, University of Erfurt

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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. 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. Interviews, scenario analyses, and case studies to inform policy recommendations.

Complementing these scenarios, the researchers will also carry out selected case studies in different global regions, which will draw primary data from 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.



HAMELIN LORIE



Laureate of the French call

Home institution : Poland, Institute of Soil Science and Plant Cultivation

Project : *Cambioscop – Carbon management towards low fossil carbon use*

Host institution : Biotechnology Institute, Toulouse; INRAE Research Chair on Sustainable Transitions towards low fossil Carbon use

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Achieving the Paris Agreement requires transiting towards economies that supply all electricity, heat, transport (road, maritime, aviation), materials, feedstock chemicals and food without fossil carbon resources. The Cambioscop project examined, essentially through Life Cycle Assessment, how to achieve this within the French economy, with the least environmental impacts possible. It built a geo-localized inventory of residual biomass resources available in France (Karan & Hamelin 2020, 2021), and modular life cycle inventories for the use of this biomass to supply: (i) “waste-to-nutrition” solutions (Javourez et al., 2021, 2022), (ii) bio-based oil production (Brassard et al., 2021, Lakshman et al., 2021), (iii) renewable gas production (Lodato et al., 2022), (iv) bio-based materials production (Shen et al., 2022a,b; Gomez-Campos et al., 2021a, b; among others from feedstock grown on marginal lands), (v) aviation propulsion (Su-ungkavatin et al. 2021, 2022; including hydrogen and electric planes) and (vi) feedstock chemicals from food waste (Teigiserova et al., 2019, 2020, 2021, 2022). These inventories can be re-used and adapted by policy practitioners and researchers. Results for food waste reinforce that food grade organic waste should be first prioritized for humans, then animals (unless the stream would have otherwise been feed directly to animals, in which case the added energy hardly compensates for the avoided crop ingredients), then recycled (as material, nutrient, energy). Unlocking feed market to non-feed quality streams unambiguously yield net benefits for most impact categories, but climate change, where anaerobic digestion (i.e. energy valorization through the production of biogas) is often more suited, especially for streams with low digestibility. Summarized conclusions for stakeholders on food and feed, but also bio-oil, -gas, aviation and bio-based materials will be soon published on the Cambioscop website.

Cambioscop also investigated the interplay between bioeconomy and soil organic carbon stocks maintenance, building on the 62,000 simulations units developed in the French 4per1000 initiative spatially characterizing the French agriculture. The question was to determine to which extent crop residues (e.g. straw) should be harvested for bioeconomy without decreasing soil organic carbon stocks, taking into account that some conversion pathways involve that a residual coproduct is returned to soils. We adapted the French soil simulation model AMG to incorporate these coproducts and their recalcitrant behaviour. We showed that after 100 years, there is more soil organic carbon in all French arable lands through harvesting all the residues, converting them to bio-oil via pyrolysis, and returning the biochar, than just leaving the crop residues unharvested and directly reincorporated to soils. This is among others due to the recalcitrance of the converted carbon. This result also applied for gasification with the return of gaschar, and applied to 88 % of the areas for hydrothermal liquefaction (return of hydrochar). With biogas (return of digestate), minor gain or loss of soil organic carbon are observed, depending on the specific geographical location.

All Cambioscop modular life cycle inventories, datasets, and R codes are available in open access on the data repository of Toulouse Biotechnology Institute. The final step of the project will be to link all these modular blocks together in order to determine, in France, for different societal scenarios from 2025 to 2050 (i) which residual biomass to allocate to the production of which products and services (and through which technology) to minimize the overall environmental impacts (not only climate change) of the transition towards a low fossil carbon economy; (ii) how much carbon from direct air carbon capture is required for this transition; (iii) the potential to induce long-term atmospheric carbon dioxide removals by sequestration in soils, while supplying the different societal demands for carbon-based products.



HILL ERIC 

Laureate of the German call

Home institution : USA, University of Texas at Austin

Project : *Nanocomposites and Materials for Energy Solutions*

Host institution : Universität Hamburg

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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. 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 photocatalysis. Collectively, these studies will lead to the engineering of mechanically robust photocatalytic materials with improved performance and low cost compared to the state of the art, in order to promote a carbon-free energy future.



RIVADA WHEELAGHAN ORESTES 

Laureate of the French call

Home institution : Japan, Okinawa Institute of Science and Technology Graduate University

Project : *CAMELEON – CO₂ conversion to C₂ products; Homogeneous Electrochemical and photochemical catalysis ; solar fuels*

Host institution : Laboratoire d'Electrochimie Moléculaire, Paris

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To reduce our dependence on fossil fuels, radical shift towards environmentally friendly sources of energy is required. However, renewable energies are intermittent, and their availability at a large-scale requires flexible and long-term (seasonal) storage.. The key to success falls on the development of new strategies to store these renewable energies through the energy density of chemical bonds. In this context, we will use a series of new developed molecular catalysts for combined CO₂ electrochemical and photo-electrochemical transformation into carbon-based fuels. We target CO₂ conversion into highly reduced C₁ species such as methane or methanol, by different molecular means upon exclusive use of Earth abundant, inexpensive first row transition metals. Moreover, we intend to develop multimetallic systems to selectively convert CO₂ into C₂ and C₂₊ products (alcohols, acids, hydrocarbons by electrochemical means. We have designed ligand platform to facilitate metal to metal cooperative effects to explore their reactivity as homonuclear systems for the promotion of multielectronic reduction of CO₂. As well as specific molecular cages.. The final goal is to integrate these catalysts into lab-scale electrolyzers or photo-electrolyzers, which will bring us one step closer to applicable technology devices that will contribute to positively impact global sustainability.



SCHULZ PHILIP



Laureate of the French call

Home institution : USA, National Renewable Energy Laboratory

Project : *InHyMat-PV – Interfaces and Hybrid Materials for Photovoltaics*

Host institution : Institut de Recherche et Développement sur l'Énergie Photovoltaïque, Paris

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In order for photovoltaics to reach the multi terawatts level required for the energy transition we need to access new material systems and routes for their implementation into solar cells that combine low costs and high performance. The focus of the InHyMat-PV project is on the design and analysis of interfaces in photovoltaics centered on emerging hybrid energy materials and hybrid organic/inorganic interfaces, such as halide perovskites, with remarkable semiconductor properties. Our main goal is to unravel, on the basis of fundamental scientific understanding, the interdependencies between the individual building blocks on a molecular level and their impact on the macroscopic optoelectronic properties. Results will encompass a technological demonstration and design rules for tailor-made interfaces for efficient, stable and scalable devices in tandem geometry. Our approach hence promises to generate a comprehensive model of the fundamental electronic processes in hybrid compounds and across interfaces: First, we will control the energetic alignment at the interfaces in high performance perovskite solar cells for enhanced charge carrier transfer. Second, we will use wet and vacuum deposition techniques to synthesize buffer- and interlayers for integrated tandem solar cell concepts. Third, we will advance and combine our means for spectroscopic operando analysis of devices to optimize cell architecture and composition. With these assets our group at IPVF aspires to be a research hub for materials science, process development and interfacial design for solar energy applications, at the forefront of the emerging field of hybrid organic/inorganic optoelectronics.



TSAI YUTSUNG



Laureate of the German call

Home institution : USA, University of Texas at Austin

Project : *Lateral multi-junctions of 2-D transition metal dichalcogenides as optoelectronic platform for transparent photovoltaics*

Host institution : Helmholtz-Zentrum Berlin für Materialien und Energie

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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) semiconductors, particularly transition metal dichalcogenides (TMDs), have suggested that their unique properties can be leveraged for new device concepts. Foundation for this are the tunable band gaps, the ability of light absorption, and the successful proof as large-area high-performance devices fabricated using scalable and inexpensive techniques. 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. Here the generation of a fundamental understanding for the correlation of the chemical material properties and the resulting physical effects, which establish the basis for the photovoltaic performance, is of great importance to systematically optimize the material properties and thereby avoid the time-consuming trial-and-error method for the investigation of new materials. Hence, in this project both, the synthesis conditions and material characteristics, are closely studied. The vapor deposition synthesis provides a clean and reproducible preparation route and, moreover, an established tool to precisely adjust the material properties, like crystallinity and lateral expansion. To draw the connection to the photovoltaic performance, the materials are then planned to be characterized extensively using a sophisticated in-house built optical setup.



TURNHEIM BRUNO  *Laureate of the French call*

Home institution : UK, Manchester Institute of Innovation Research

Project : *Governing destabilisation pathways and phase-out*

Host institution : Laboratoire Interdisciplinaire Sciences Innovations Sociétés (LISIS), Marne la Vallée

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Despite the significance of the 2015 Paris Climate Agreement, national pledges are still far from enough and progress with low-carbon transitions needs to be significantly stepped up. More ambitious, accelerated, and feasible low-carbon pathways are required. These need to address the lock-in and inertia in established systems and the overlooked challenges related to destabilisation processes and the phase out of high-carbon activities. Understanding destabilisation as a socio-technical process is the key contribution of WAYS-OUT. The destabilisation of existing systems is an emerging research and policy concern related to socio-technical transitions. Accelerating low-carbon transitions requires not only the deployment of alternative options, but also dealing with inertia and lock-in of existing systems and actors that tend to resist, slow down or prevent transition efforts.

This is often forgotten or ignored, particularly in policy debates and future visions. Relying only on emerging options and innovations without considering the destabilisation and discontinuation of incumbent systems considerably reduces the possibility of socio-technical transitions. Accelerating low-carbon transitions requires the active phase-out of high-carbon activities, with destabilising effects on existing systems which can only be appropriately handled if their potential trajectories and outcomes are anticipated.

The main objective of WAYS-OUT is to generate systematic and interdisciplinary knowledge on destabilisation to inform policy in support of more ambitious and feasible transitions pathways. The project combines socio-technical and modelling approaches. WAYS-OUT contributes to efforts anticipating destabilisation arising from decarbonisation pathways and exploring the prospects for turning destabilisation challenges into opportunities for managed transitions.



ZURCH MICHAEL



Laureate of the German call

Home institution : USA, University of California, Berkeley

Project : *Quantifying Ultrafast non-Equilibrium dynamics in semiconductor quantum nanomaterials for nExt geNERation eneRGY Materials – QUESTforENERGY*

Host institution : Friedrich-Schiller-Universität Jena

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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 deviceready than the widely known graphene due to their optical bandgap. The intriguing possibilities stemming not only from low-loss charge transport combined with a designable 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.

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