Shaping Transatlantic Climate Research Collaboration

MAKE OUR PLANET GREAT AGAIN

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MAKE OUR
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GREAT
AGAIN

On June 1, 2017, when the international cohesion around climate change mitigation goals that led to the adoption of the 2015 Paris Agreement appeared weakened, French President Emmanuel Macron issued a full-throated call to rally together to “make our planet great again.”

The French government has demonstrated its commitment to achieving this goal by mobilizing exceptional resources for international mobility and collaboration in climate and environmental science research. Germany quickly joined forces with France on this initiative.

Students and scientists worldwide were invited to apply for short and long-term academic and research fellowships in France. Many North American scientists embraced the opportunity to apply. Among them, 24 awardees received scholarships for research fellowships with French climate and environmental science laboratories lasting three or more years.

In addition to making an outstanding contribution to research on climate and the environment, these scientists have become advocates for further collaboration between the research institutions in their home and host countries, not to mention the countries themselves.

As the first phase of the Make Our Planet Great Again program draws to a close, I would like to officially invite the fellowship recipients to the Embassy of France in the United States on October 17-18, mere weeks before the 27th Conference of Parties of the United Nations Framework Convention on Climate Change and just a few months before the Paris agreement is scheduled to be reviewed. Fellows are invited to share the results of their impressive research and provide the leaders of American and European scientific institutions with valuable insight into the best ways to shape the future of transatlantic cooperation and approach climate change mitigation and adaptation worldwide.

Philippe ETIENNE
Ambassador of France
to the United States

Shaping Transatlantic Climate Research Collaboration

MAKE OUR PLANET GREAT AGAIN

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**“Because wherever we live,
whoever we are,
we all share the same responsibility:
Make our planet great again.”**

— President Emmanuel Macron
Elysée Palace, Paris – June 1, 2017

History of the “Make Our Planet Great Again” initiative

The “Make our Planet Great Again” initiative was launched by French President Emmanuel Macron on June 1, 2017 amid international concern and incertitude following then-President Donald Trump’s announcement of the US withdrawal from the 2015 Paris Agreement.

France expressed its readiness to lead the international effort to keep pursuing the Paris Agreement goals, along with a new funding scheme to host climate researchers, entrepreneurs, students, associations and NGOs from around the world.

As soon as June 8, the French government opened an online portal allowing candidates to apply for a wide range of projects: short-term or long-term research stays, post-doctorate positions, graduate (master or PhD) studies, collaborations with laboratories in France. 1,800 formal applications were received, among which a majority from the United States (61%).

Germany announced its intention to join the initiative during the French-German summit held in July 2017.

Long-term research stays

The action concerning long-term research stays (3-5 years) in French research laboratories, which is the focus of the present booklet, was placed under the joint responsibility of the French National Research Agency (ANR) and the French National Center for Scientific Research (CNRS). Institutions hosting laureates were required to co-fund these research stays on par.

Candidates were given the possibility to apply in three thematic areas:

- **Earth system science:** knowledge and monitoring of the physical, chemical, biological, ecological and social mechanisms that underpin global and regional environmental changes. This includes an understanding of how these mechanisms have interacted in the past, and how they are likely to evolve in the future as well as scientific assessments that are relevant to diverse contexts ranging from global to local scale.
- **Climate change and sustainability sciences:** critical knowledge gaps in ways of addressing sustainable development challenges in the context of global and climate changes. This includes meeting basic needs for a growing human population in a stressed ecosystem and how societies may address global environmental and sustainability challenges.
- **Energy transition:** transition from fossil fuels towards innovative zero carbon energy sources, associated to carbon sequestration and usage strategies.

18 laureates were announced during the “One Planet Summit” held in Paris on December 2017, among whose 13 from the United States.

14 more laureates, among which 5 from the United States, were announced in 2018, and 11 more in 2019 (3 from the United States), bringing the total number of French-funded laureates to 43, among whose 21 from the United States.

On the German side, the Make Our Planet Great Again – German Research Initiative (MOPGA-GRI), managed by the *Deutscher Akademischer Austauschdienst* (DAAD), is funding 13 more projects taking place in German laboratories.

A joint MOPGA kick-off conference was held in Paris on October 1, 2019 in the presence of French and German research ministers Frédérique Vidal and Anja Karliczek, and a mid-term conference was held in Strasbourg, France, on November 23-24, 2021. The final meeting is scheduled in Berlin, Germany on December 6-7, 2022.

Post-doctorate fellowships, graduate studies, short-term research stays

Campus France, the French agency for the promotion of higher education, international student service and international mobility, manages applications and grants for post-doctoral, graduate studies fellowships (master, PhD) and short-term research stays. Five editions of the call have been issued since the launch of the initiative. Applications are evaluated by experts appointed by the French Ministry of Higher Education and Research.

Fresh funding received by the Embassy of France in the United States also allowed to increase the numbers of the beneficiaries, in fields relevant to the Make Our Planet Great Again initiative. The Chateaubriand program supports talented doctoral students from American universities to conduct research stays in France over a period for 4 to 9 months, in the framework of joint projects between French and American research laboratories.

Bilateral research collaborations

This exceptional funding was also used to increase the number of projects funded in topics related to Climate and Earth science in the full array of existing bilateral collaborations programs managed by the Embassy of France:

- The Transatlantic Research Partnerships program (formerly Thomas Jefferson Fund);
- The French-American Doctoral Exchange program (FADEX);
- The bilateral endowment funds established between France and a number of American universities: UC Berkeley, UC Stanford, University of Chicago, UT Austin.

Workshops and seminars

Additional events have been also organized under the MOPGA label, such as a workshop to launch the France-MIT Climate Program or a seminar on the possible exploitation of the data provided by the schooner Tara Oceans.

The laureates at the official kick-off conference on October 1, 2019 in Paris with French and German ministers of research Frédérique Vidal and Anja Karliczek.

Earth System Science

laureates

Venkatramani **BALAJI**

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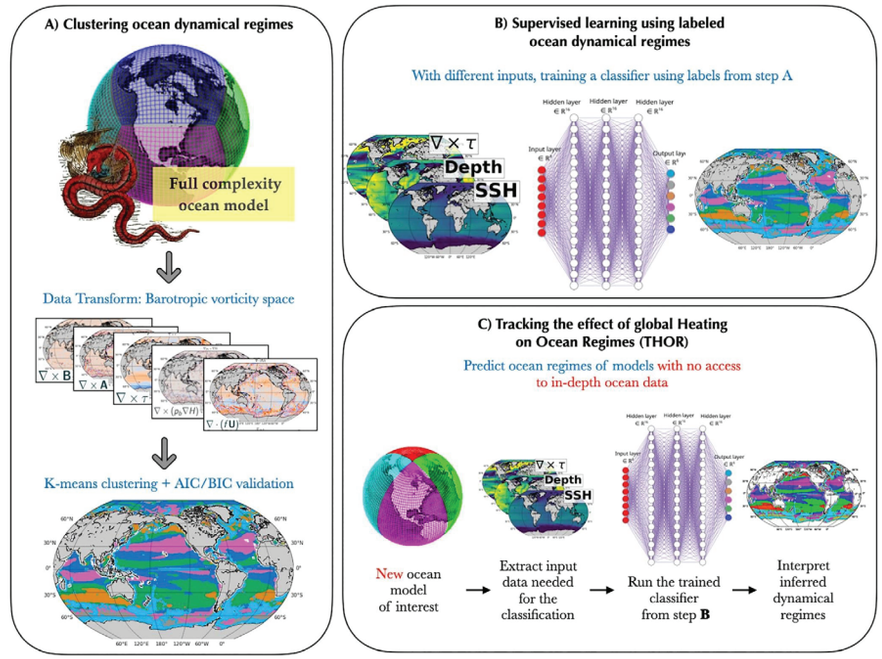
Research

Project Hermès – High Resolution Modeling of the Earth System (HRMES)

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 or emulators of the Earth system, to explore uncertainties in the system using ensembles that are beyond possibility with the full model. The unique feature of Project Hermès is the combination of computationally challenging simulations and fast models for uncertainty exploration.



From Sonnewald and Lguensat (2021), illustrating the Projet Hermès approach of using deep learning to convert high resolution models into dynamical understanding.

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Ashley **BALLANTYNE**

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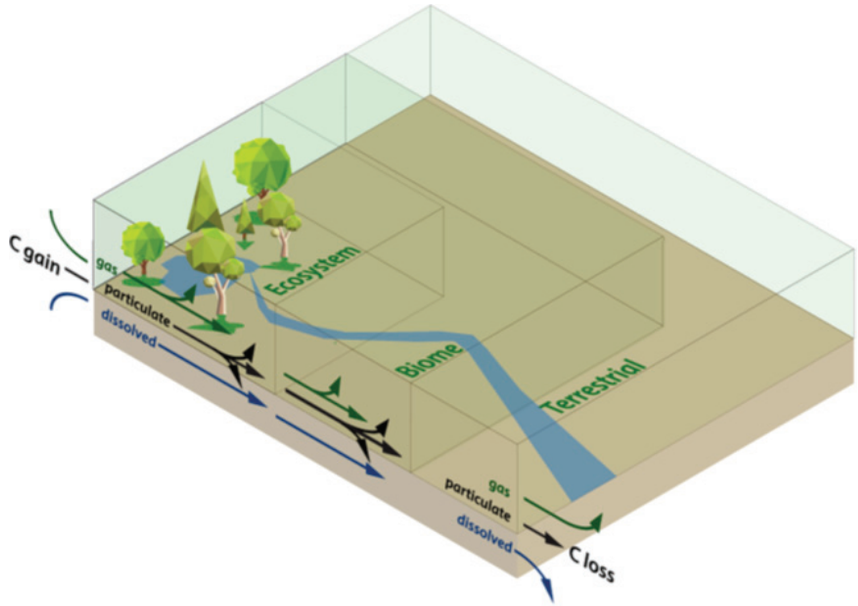
Host institution Laboratoire des Science du Climat et de l'Environment (LSCE), Saclay, France

Research

Process Oriented Model Evaluation Linked to Observations (POMELO)

Our project focused on Process Oriented Model Evaluation Linked to Observations (POMELO) is a trifecta of three research topics focusing on sensitive regions for potential carbon-climate feedbacks:

1. Developing a global water stress indicator based on remote sensing land surface temperature (LST) data and testing this water stress indicator to identify tropical regions sensitive to radiation, soil water supply, and atmospheric water demand. Our preliminary results indicate that certain tropical regions appear to have undergone a shift in sensible heat sink from the atmosphere to a sensible heat source.
2. Evaluating the sensitivity of peatland carbon fluxes to drying. We are combinining experimental and model simulation data to better predict the CO_2 and CH_4 fluxes from peatlands at high latitudes. Our empirical and simulation results suggest that under drying conditions peatland carbon dynamics may shift from a CH_4 source to a CO_2 sink.
3. Lastly, We are also investigating the carbon tunover time in living vegetation by compiling a large forest inventory dataset and comparing this with model simulations. Thus far we have discovered that temperate forests have the longest turnover time among the worlds forests due to relatively high biomass and low mortality rates.



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Frédéric **BOUCHARD**

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Research

Permafrost and Greenhouse gas dynamics in Siberia (PEGS)

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 (CO_2, CH_4) 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 acted as CO_2 sinks and strong sources of CH_4 during some seasons, while recent 'thermokarst' (thaw) lakes were moderate to extremely high sources of CO_2 and CH_4, with considerable accumulation of greenhouse gas under the ice cover (winter) or in the deepest water layers (summer).

A thermal erosion 'gully' (ravine) formed in ice-rich permafrost in central Yakutia, eastern Siberia, in August 2019. The thawing of permafrost exposes massive ice wedges tens of thousands of years old, releasing water, sediments, and organic matter in the environment. *Photo credit: Ludwig Jardillier, Université Paris-Saclay.*

Publications

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Julien **BOUCHAREL**

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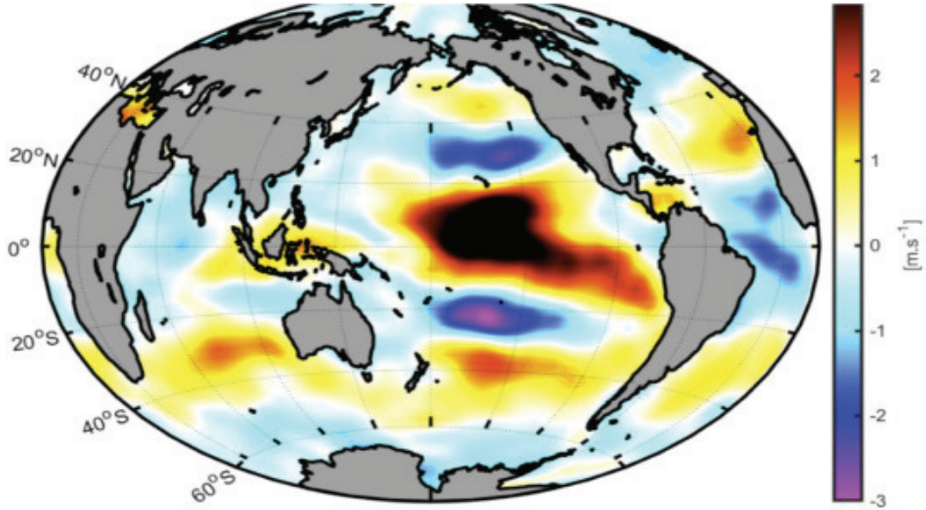
Research

Tropical Cyclone Activity and Upper-Ocean Dynamics (TROCODYN)

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 dynamicson 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.

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James **CLARK**

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Research

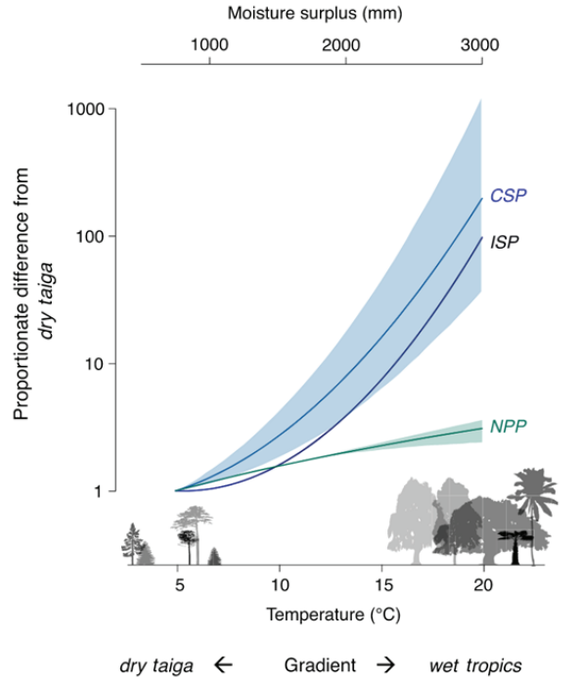
Forecasting Biodiversity Change (FORBIC)

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.

Net primary production (NPP) shows a 3-fold increase from boreal to wet tropics, while seeds per tree basal area (ISP) increases 100-fold, and seeds per forest area (CSP) increases 250-fold.



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Louis **DERRY**

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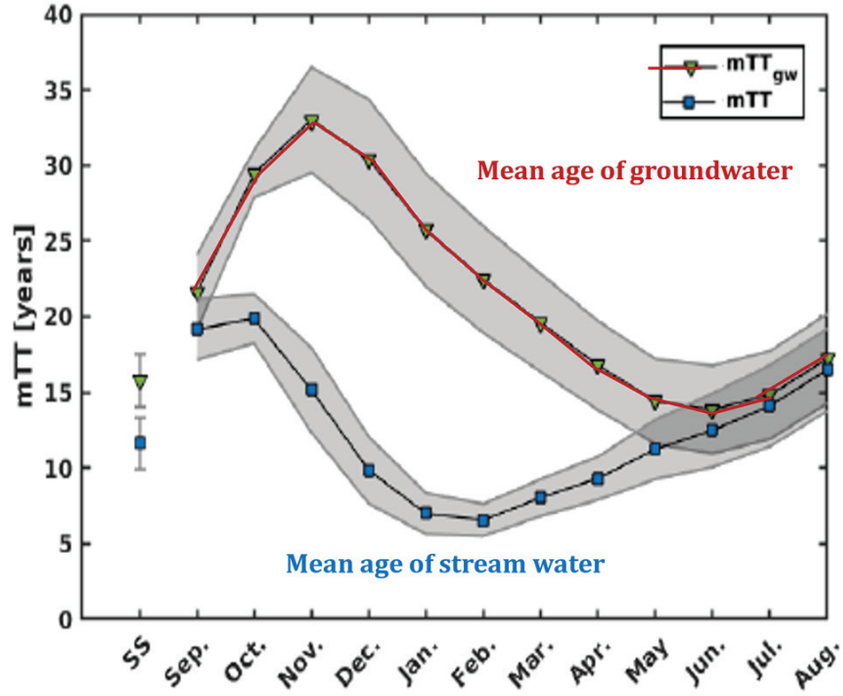
Host institution Institut de Physique du Globe de Paris (IPGP), Paris, France

Research

The Critical Zone as a Non-Steady State Biogeochemical Reactor (CZ-TOP)

Rivers export natural and anthropogenic solutes from landscapes in complex ways. What is transported depends on the ways in which water entering the landscape can react with the subsurface soil and rock. This in turn depends on the pathways the water follows and how long it takes to travel from the entry point on the surface to the exit point at the stream, the concept of "water age." River flows vary greatly with season and storm events, and the materials transported by rivers vary as well. The variation in river flows and material transport are reflected in water quantity and quality, and both of those properties are evolving and will continue to evolve under a changing climate.

We are using the behavior of streams and the Critical Zone to climate events (storms) to explore and understand the response of the hydrogeochemical system to new forcing. We combine non-steady state hydrologic models that predict flow paths and the water ages with reactive tracers and reactive transport models that indicate how water chemistry ("water quality") responds to events (drought or flood). Reactive chemistry varies with water age distribution and flow path on many time scales.



Mean transit time ("age") model for groundwater and stream water at the Guillec River, Bretagne, showing large seasonal variations in the "age" or transit time of water that enters the basin as rain and leaves later as stream water. (Marcais et al. 2022)

Publications

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William **DEWAR**

Home institution Florida State University, USA
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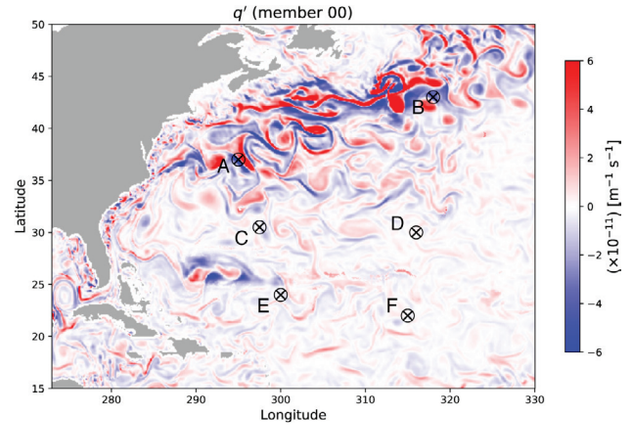
Research

Consistent OceaN Turbulence for ClimaTe Simulators (CONTaCTS)

CONTaCTS has focused on the study of sub-mesoscale and mesoscale phenomena and subgrid-scale parametrizations for the next generation of climate simulators. Realistic North-Atlantic NEMO simulations performed in France have been used to analyze the submesoscale turbulence at the ocean surface. These explicit submesoscale resolving simulations have been shown consistent with a recently proposed parameterization[g]. These simulations are also being used to examine submesoscale impacts on kinetic energy spectra[b,f] and on their interactions with topography.

We have also analyzed a realistic North Atlantic ocean ensemble to quantify the influence of the mesoscale turbulence on kinetic energy[c,e], tracer transport[d,i] and vertical exchanges within and across oceanic boundary layers. We have demonstrated the unique role of the separated Gulf Stream in establishing circulation equilibrium in the North Atlantic[a], a result that likely generalizes to all ocean basins. We have developed novel methods for investigating the cross-scale energetic dynamics of the ocean in realistic settings[h,k] and quantified intrinsic ocean variability contributions to the climatically important Atlantic Meridional Overturning Circulation (AMOC)[j].



Surface eddy Ertel's PV realized by one of our ensemble members. The U.S. east coast appears; the Gulf Stream and its extension into the open Atlantic are visible. Locations in the Gulf Stream near to separation at Cape Hatteras and North Atlantic Current are marked as are other locations in the North Atlantic interior and gyre retroflection with six regions in total named from A to F. We have investigated the kinetic energy wavenumber spectral structure at these locations and compared them.

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[c] Uchida, T, Q Jamet, A Poje and WK Dewar, An ensemble-based eddy and spectral analysis, with application to the Gulf Stream, *Journal of Advances in Modeling Earth Systems,* 2021, doi:10.1029/2021MS002692

[d] Uchida, T, Deremble, B, Dewar, WK, & Penduff, T, Diagnosing the Eliassen-Palm flux from a quasi-geostrophic double gyre ensemble. In: Earth-cube annual meeting. doi: 10.5281/zenodo.5496375737.

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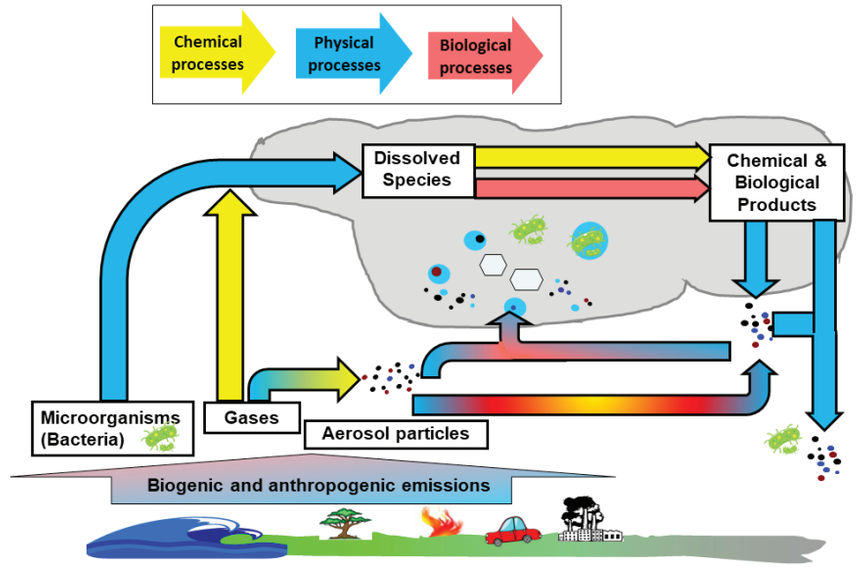
Research

Modeling Biologically Driven Processes in Clouds (MOBIDIC)

MOBIDIC aims at improving the representation of biological processes in the atmosphere. Cloud droplets are media where chemical, physical and biological processes occur that modify chemical and biological constituents. Resulting composition of cloud water affects rain composition which impacts air quality and soil composition; 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 has not been estimated yet due to the lack of suitable numerical models. In the current project, laboratory and ambient data (e.g., from the local Puy de Dôme station, Auvergne, France) in clouds and cloud-free air have been used to explore the microbial activity in the atmosphere. These data are used to assess the importance of biological processes for chemical budgets in the atmosphere and for the role of various atmospheric conditions on microbial activity.



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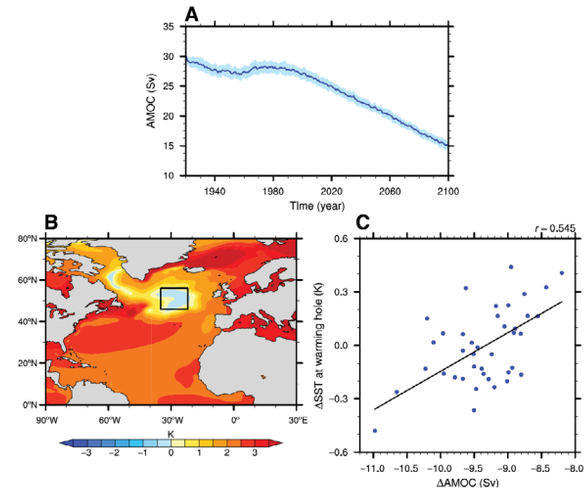
Research

Arctic climate change, global ocean circulation and basin interconnections (ARCHANGE)

With the accelerating global warming, we understand more and more that different components of the climate system are tightly interconnected. How well state-of-the-art climate models represent those interconnections strongly affects the fidelity of future climate projections. In particular, future changes in the Atlantic meridional overturning circulation (AMOC) – the key component of the global ocean "conveyor belt" – remain uncertain.

It is generally expected that the AMOC will weaken significantly by the end of the 21st century, but the rates of AMOC slowdown vary greatly across climate models. Whether the AMOC might eventually collapse is also debated. This uncertainty arises because the AMOC is influenced by a variety of local and remote processes, some acting to speed up the AMOC slowdown, others to stabilize this circulation. In turn, AMOC changes influence a broad range of climate and weather phenomena ranging from El Niño to tropical cyclones.

The overarching goal of ARCHANGE is to study these processes and their climate impacts. For example, we investigate how two salient features of global warming – Arctic sea ice decline and enhanced warming of the tropical Indian ocean (TIO) – modulate the AMOC. Understanding these interconnections is an urgent, yet challenging problem of climate science.



The strength of the Atlantic Meridional Overturning Circulation (AMOC) and the North Atlantic Warming Hole (NAWH) in large ensemble simulations of the Community Earth System Model (CESM). (A) The AMOC strength during 1920–2100 from CESM simulations (blue, ensemble mean; light blue, ensemble spread). (B) Ensemble mean sea surface temperature (SST) change (years 2061–2080 minus 1961–1980) in the North Atlantic in CESM large ensemble simulations. (C) The scatter plot of SST changes over the NAWH region [black box in (B)] and AMOC strength changes in CESM simulations (blue dots for individual ensemble members). The best-fit line (black) is also shown. After Liu et al. 2020.

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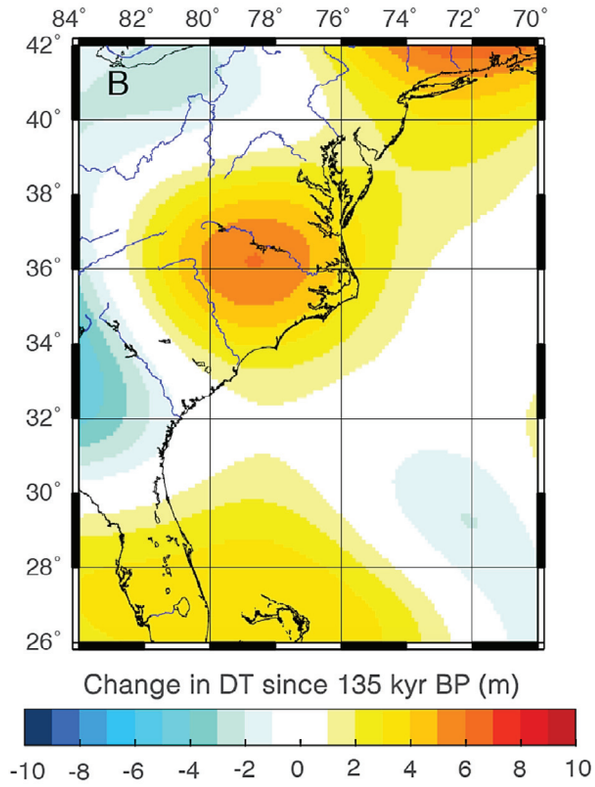
Research

Geodynamic perturbations of climate signals (GYPTIS)

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,"v 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.



Predicted change of dynamic topography (DT) since the last interglacial period (135 thousand years ago) in the Eastern US based on computational geodynamic simulations of the evolution of 3-D structures inside the solid Earth. Units in the scale bar are meters. Figure from *Austermann & Forte* (2019, doi.org/10.22498/pages.27.1.18).

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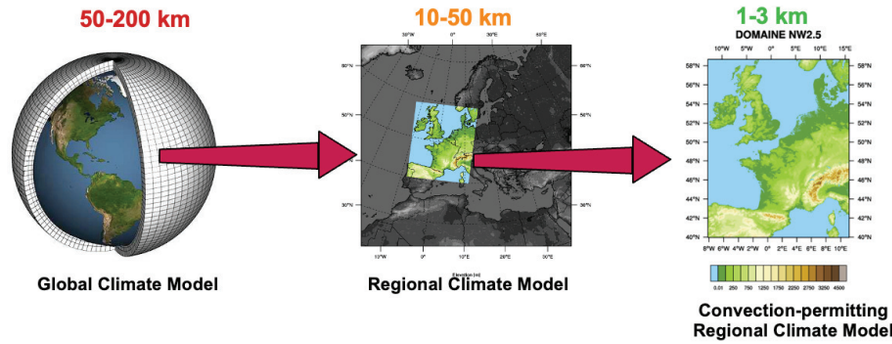
Research

Impacts of climate change at the kilometer-scale over Europe (KM-IMPACTS)

With the recent increase in computational power, long 1-3 km resolution 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 addresses 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.

A thorough analysis of global climate model (GCM), classic RCM and new CPRCM simulations is ongoing to assess the robustness of their climate-change signals. One major aspect of this project consists in the analysis of the changes of fine-scale meteorological phenomena over the Mediterranean Islands in climate change simulations Another interest is the impacts of climate change on flash floods using improved hourly meteorological variables over southeastern France. Finally, another study focuses on the future evolution of the urban climate of some large European cities using the more realistic simulated local meteorological variables. Up to now, CPRCM have shown improvements of local scale simulated meteorological variables, which is promising for more robust climate change signals that are going to be analyzed in the coming months.



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Research

Predicting future oceans under climate change (4Oceans)

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 4Oceansmopga project seeks to investigate marine organisms' physiological, ecological and adaptive responses to ocean warming and ocean acidification. This is key to advancing our understanding of marine species and ecosystem resilience under present conditions and future climate scenarios.

One of the major findings is that the Mediterranean Sea experienced a series of marine heatwaves during the period between 2015 and 2019 that affected all regions of the basin, which resulted in recurrent mass mortality events of marine species. Some of the most affected species are key to maintaining the functioning and biodiversity 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. Combined, the dataset provides new insights into resilience and ecosystem shifts in response to 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 calycularis* 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.

We are also studying gene expression as well as skeletal structure. Finally, 4Oceans endeavors to do science that can contribute to assessing the potential and capacity of marine macrophytes (e.g. seagrasses, macroalgae) to act as biogenic refugia against ocean acidification. To this end, we have completed field surveys to assess the level and potential of pH buffering of selected macrophytes, 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: http://4oceansmopga.com

Publications

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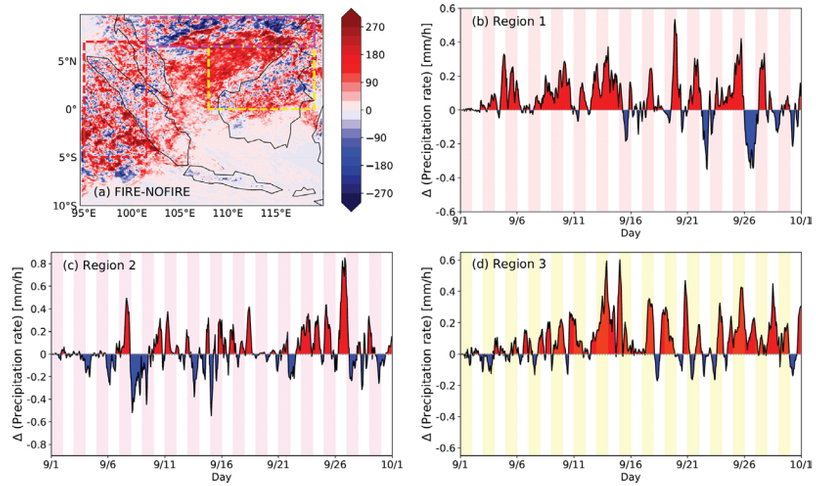
Research

The Roles of Aerosols in Climate and Environment (EUROACE)

EUROACE project is to advance our understanding about the impacts of atmospheric aerosols on global and regional climate particularly through aerosol-cloud interaction, with a specific emphasis on the influence of anthropogenic aerosols from different sources on precipitation. Using high-resolution regional models, we have demonstrated that aerosols emitted from frequent biomass burnings in Southeast Asia not only cause detrimental haze pollution but also substantially change the strength and distribution of precipitation. By applying various machine learning methods in data analysis, we have also identified a persistent increasing trend of extreme monsoonal rainfall events over a large part of India in the past century.

Our modeling study have also revealed the role of aerosols resulted from massive urbanization in causing such an increase. In addition, we have developed a new rain formation parameterization for regional models using machine learning algorithms, and a deep learning machine to analyze and forecast certain environmental and weather extremes including severe haze events, hailstorms, and extreme precipitation events during the monsoon season.



(a) Difference in accumulated precipitation (mm) over the month of September between two model simulations, one included (FIRE) and the other excluded (NOFIRE) aerosols from fires in Southeast Asian islands. (b–d) Time series of regional mean precipitation rate (mm per hour) differences (FIRE - NOFIRE) in 3 different analyzed regions. These results suggest that aerosols emitted from frequent biomass burnings in Southeast Asia can substantially change the strength and distribution of precipitation besides causing detrimental haze pollution. (From Takeishi and Wang, 2021).

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Climate Change

laureates

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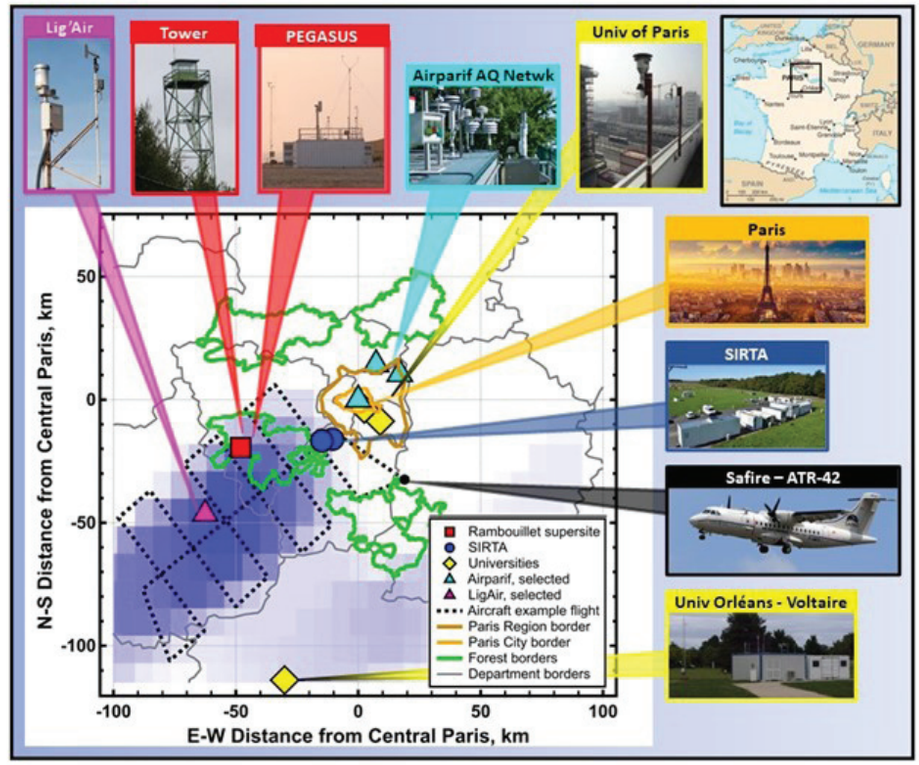
Research

Atmospheric Chemistry of the Suburban Forest (ACROSS)

The central component of ACROSS is a comprehensive summertime field study with many instruments for the measurement of primary and secondary constituents. Measurements will be made from research aircraft, a tower located in a forest, tethered balloons and/or drones, and mobile platforms. Observations from the field study will be analyzed in a variety of ways involving statistical approaches and comparisons with different types of numerical models.

The results of the campaign will be widely disseminated through presentations and peer-reviewed publications. Significant broader impacts are expected including training of students, public outreach, and providing useful information to policymakers. The ACROSS observations are expected to provide a unique dataset that will improve understanding of fundamental processes and that can be used to improve model representations of processes that are operative in these environments.

The campaign validated our experimental design to make measurements inside and outside of the Paris pollution plume with the aircraft and ground sites. The plume clearly dilutes into background air while undergoing chemical oxidation processes. Since the campaign was just completed in July 2022, detailed analysis will need to wait for submittal of final data and use of models and statistical methods to interpret the observations.



Publications

Cantrell, C. A. and V. Michoud, An Experiment to Study Atmospheric Oxidation Chemistry and Physics of Mixed Anthropogenic–Biogenic Air Masses in the Greater Paris Area, Bulletin of the American Meteorological Society, 103(8), https://doi.org/10.1175/BAMS-D-21-0115.1, 2022.

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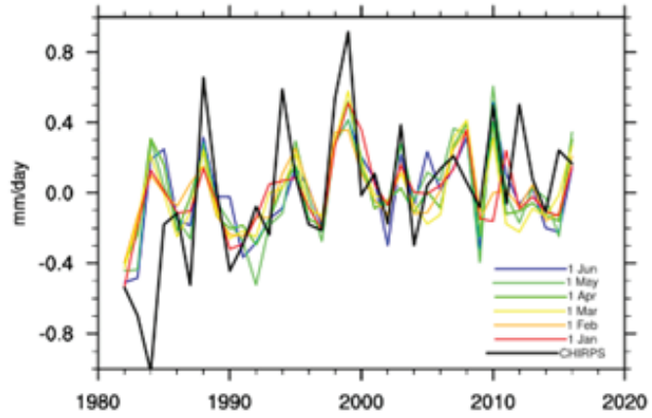
Research

PROcess-based Diagnostics of Uncertainty in Climate change projections in the Tropics (PRODUCT)

In the tropics, climatic impact – e.g., on agriculture, water resources and public health – is driven by variation in precipitation more than in temperature. Indeed, our own analysis of the relationship between food security and precipitation in Senegal reveals the effect of widespread drought (Ilboudo Nébié *et al.* 2021), highlighting the sensitivity of farming households to climate (Giannini *et al.* 2021).

Yet, it is precisely in these tropical regions that future precipitation outcome appears most uncertain. In this project we opportunistically undertook the analysis of multi-model ensembles, whether simulating the historical past, predicting seasonal to interannual fluctuations or projecting future change in Sahel rainfall, to advance process-based understanding of variability and change in precipitation.

These analyses not only validate the progress made in model simulations of relevant processes (Giannini *et al.* 2020). They also test the robustness and limitations of an interpretation (Giannini *et al.* 2013, in *Environmental Research Letters*) which seeks 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 (Herman *et al.* 2020).



From figure 2 in Giannini et al. (2020, in Geophys. Res. Lett.): the performance of the North American multi-model ensemble in predicting Sahel-wide rainfall (the average over 10–20°N and 20°W-40°E) during the July-September rainy season. The black line represents anomalies, positive if above, and negative if below the long-term mean. The color lines represent anomalies as predicted as early as January, in red, and as late as June, in blue. Overall, the skill is comparable, highlighting the improvement in the coupled ocean-atmosphere models used for seasonal prediction in the past ~10 years, and attesting to the potential value of seasonal prediction in managing food security at the regional scale.

Publications

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

Research

Multi-Catalyst Systems for Energy Efficient Chemical Synthesis (PRACTACAL)

Catalysis is crucial to basic and applied chemistry; it is the key to minimization of energy usage. Catalysis and its implementation in large chemical companies can contribute significantly to sustainable development. Our aim is to design and develop new catalysts and catalytic methods for chemical synthesis, combining them for maximum effect. The following key advances were achieved as a result of MOPGA funding:

1. A protecting group-free and diastereo- and enantioselective routes for accessing a many Z-homoallylic alcohols was developed. The utility of the approach was demonstrated by a succinct and practical total synthesis of mycothiazole, an anticancer agent. This advance will facilitate producing anti-cancer compounds with generation of minimal chemical waste.
2. The first strategy for catalytic cross-metathesis involving two allenes was developed. Allenes are crucial in drug discovery, as they can serve as versatile substrates for a wide range of reactions. Moreover, allenes are central moieties in a large number of important bioactive compounds. This advance will provide access to many new allenes at little or no cost to the environment.

Publications

"A Catalytic Approach for Enantioselective Synthesis of Homoallylic Alcohols Bearing a Z-Alkenyl Chloride or Trifluoromethyl Group. A Concise and Protecting Group-Free Synthesis of Mycothiazole," R. J. Morrison, F. W. van der Mei, F. Romiti, A. H. Hoveyda, J. *Am. Chem. Soc.* 2020, 142, 436.

"Cross-Metathesis of Allenes. Mechanistic Analysis and Identification of a Ru-CAAC as the Most Effective Catalyst," S. A. Gonsales, Z. C. Mueller, F. Zhao, P. H. S. Paioti, L. Kazamarin, J. Wan, F. Liu, K. N. Houk, A. H. Hoveyda, J. *Am. Chem. Soc.* 2021, 143, 20640.

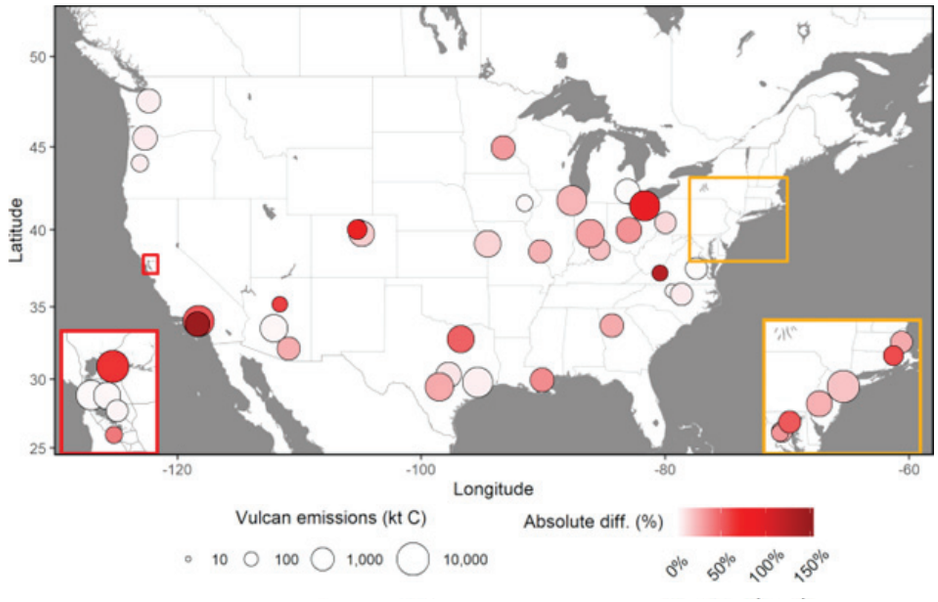
Thomas **LAUVAUX**

Home institution Pennsylvania State University, USA
Host institution Laboratoire des Sciences du Climat et de l'Environnement (LSCE), Saclay, France

Research

Quantification of urban greenhouse gas emissions (CIUDAD)

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.

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Lauvaux T., Gurney K.R , Miles N.L. , Davis K.J et al (2020). Policy-Relevant Assessment of Urban CO2 Emissions. Environmental Science & Technology 2020 54 (16), 10237-10245 DOI: 10.1021/acs.est.0c00343

Carol E. **LEE**

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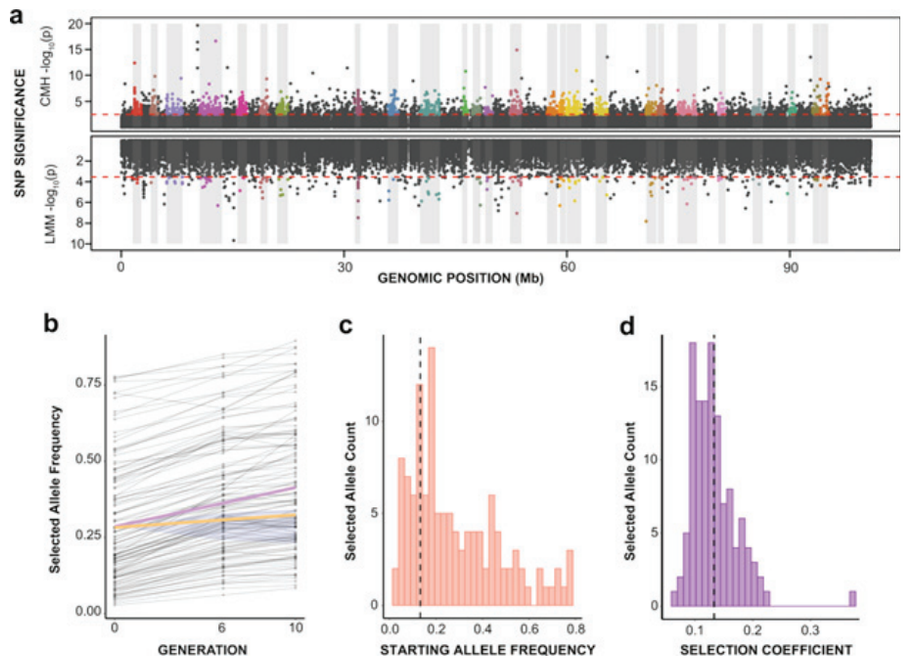
Research

Rapid Evolutionary Responses to Climate Change

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.



Publications

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Camille **PARMESAN**

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Research

Climate Change Impacts on SpecieS (CCISS)

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. This research will continue 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.

Egg placement in a Pedicularis*-feeding population at Rabbit Meadow.*

(a) A natural clutch of E. editha *eggs on* P. Semibarbata *at Rabbit Meadow on July 25, 2019, adjacent to grazed leaves.*

(b) A Rabbit Meadow butterfly, numbered '6' with a purple permanent marker, showing positive geotaxis by placing her eggsat the base of a Pedicularis.

Publications

Parmesan C., Singer M.(2022). Mosaics of climatic stress across species' ranges: tradeoffs cause adaptive evolution tolimits of climatic tolerance. Phil. Trans. R. Soc. B377: 20210003. https://doi.org/10.1098/rstb.2021.0003

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Delphine **RENARD**

Home institution University of California, USA
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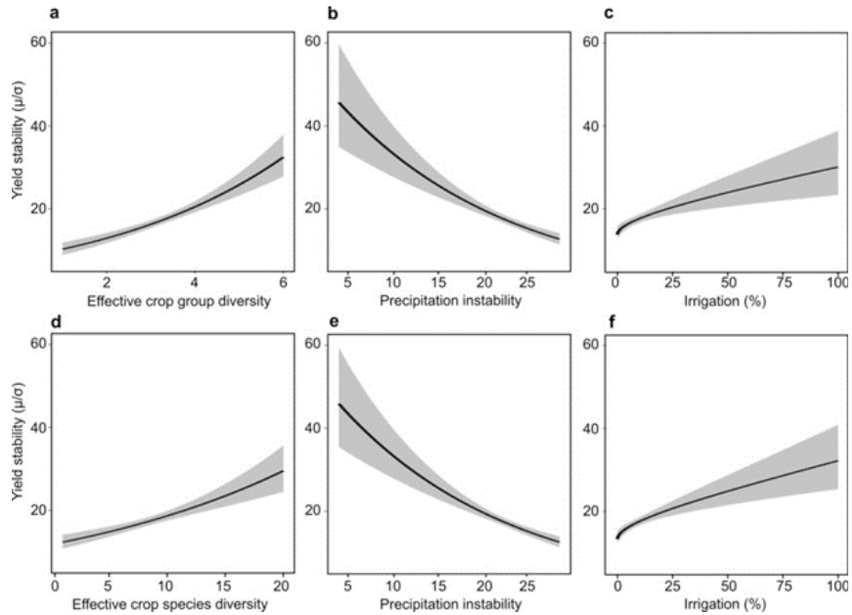
Research

AgrobiodiverSity for a food-Secure planET (ASSET)

Ensuring food security under a changing climate is among societys 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.



Main determinants of national caloric yield stability a–f, Magnitude of the change in national yield stability as dependent on effective crop group diversity (a) and effective species diversity (d), precipitation instability (b, e) and irrigation (c, f). a–c, Values of national yield stability are predictions from the multiple regression model using effective crop group diversity (Extended Data Table 2a). d–f, Values of national yield stability are predictions from the multiple regression model using effective crop species diversity (Extended Data Table 2b). Predicted values were back-transformed from log-transformation, calculated using the observed range of the three predictors and keeping all the other predictors at their mean values. The grey bands represent the regression 95% confidence interval.

Publications

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Valéry **RIDDE**

Home institution Université de Montréal, Canada
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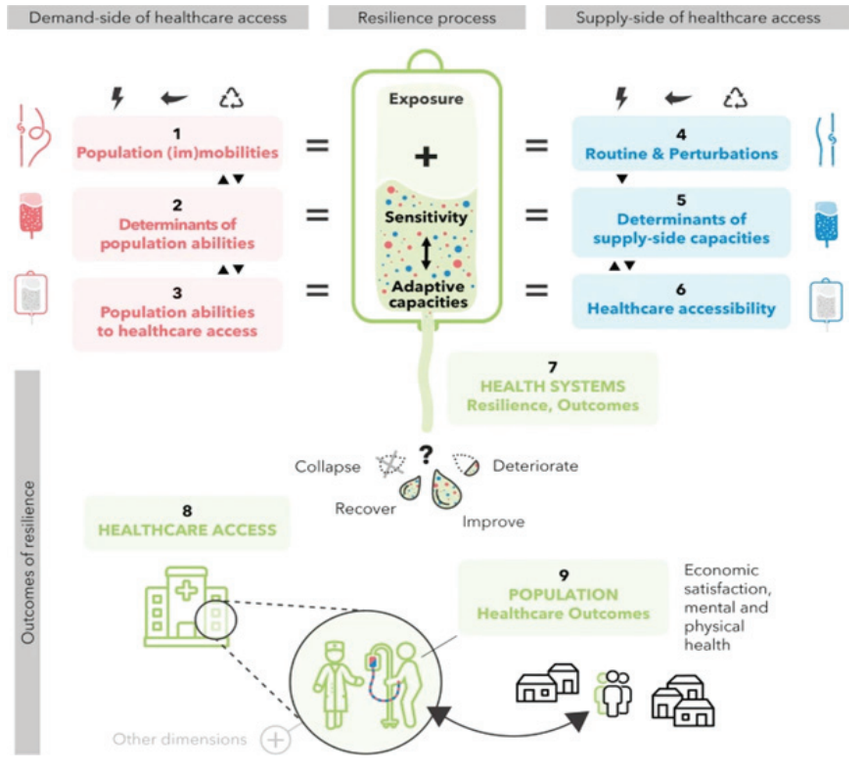
Research

Climate Change, Migrations and Health Systems Resilience in Haïti and Bangladesh (CLIMHB)

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 organized and notes of policies will be broadcast to decision-makers and representatives of civil and international organizations (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).



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Clech L., Meister S., Belloiseau M., Ridde V.,et al. Healthcare system resilience in Bangladesh and Haiti in times of global changes (climate-related events, migration and Covid-19): an interdisciplinary mixed method research protocol. BMC Health Serv Res 22, 340 (2022). https://doi.org/10.1186/s12913-021-07294-3

Ramachandran **SUBRAMANIAN**

Home institution Carnegie Mellon University, USA
Host institution Observatoires des Sciences de l'Univers - Enveloppes Fluides de la Ville à l'Exobiologie (OSU-EFLUVE) / Laboratoire Interuniversitaire des Systèmes Atmosphériques, Créteil, France

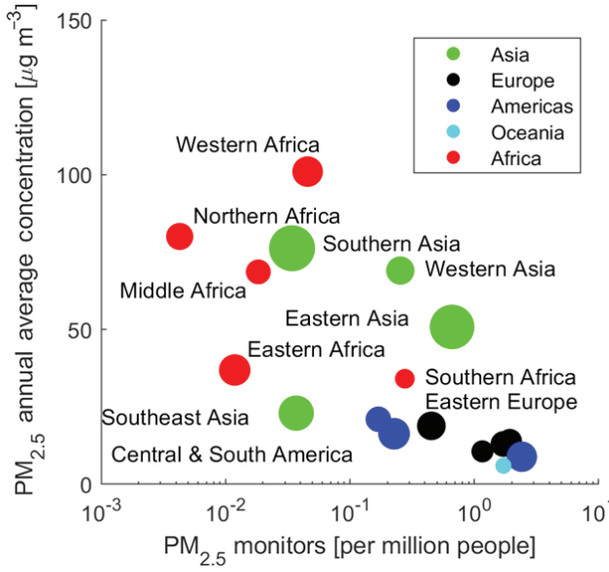
Research

Make Air Quality Great Again (MAQGA)

Air pollution is the largest environmental health risk, causing millions of premature deaths each year worldwide. Monitoring infrastructure is critical to managing and improving air quality. But global inequality in funding means that while cities like Pittsburgh, PA, USA and Paris, France have several reference EPA- or TUV-certified monitors, major African cities like Nairobi, Accra, Abidjan, and Kigali did not have any reference monitors till recently. The Make Our Planet Great Again (MOPGA) project 'Make Air Quality Great Again', in collaboration with African, American, and Australian partners, has established Africa qualité de l'air (AfriqAir, http://www.afriqair.org/), a transcontinental hybrid network of low-cost sensor nodes and reference monitors to fill in these data gaps.

Careful characterization of the low-cost sensors is essential, usually by collocation with a reference monitor. We can improve our knowledge of air pollution across under-monitored cities by combining ground sensors with satellite data. We find that car-free Sundays in Kigali, Rwanda can improve air quality as local sources include traffic and domestic cooking contribute as much as 50% of ambient PM2.5 in the wet seasons. We are simulating air pollution over East Africa using the French CHIMERE model, which will be used to evaluate future mitigation scenarios and recommend policy changes.

Estimated annual average PM2.5 concentration versus the density of regulatory-grade monitoring stations across several global regions Colors correspond to continents, and sizes roughly correspond to total regional population. This graphic is based on information available from the Global Health Observatory (WHO, 2017).



Publications

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Energy Transition

laureates

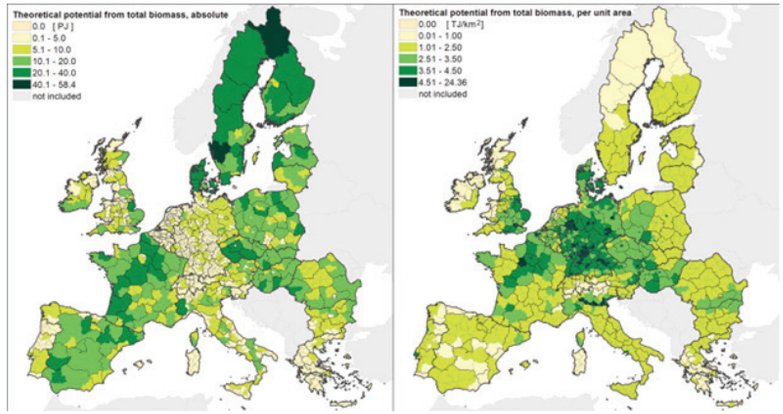
Lorie **HAMELIN**

Home institution Institute of Soil Science and Plant Cultivation, Poland
Host institution Toulouse Biotechnology Institute (TBI), Toulouse, France

Research

Carbon management towards low fossil carbon use (CambioSCOP)

Bioeconomy, i.e. the use of biogenic carbon for products and services where fossil carbon is used today, involves tapping into the potential of renewable biological ressources and the limited land available to grow these. Yet, it is seen as essential to induce net carbon dioxide removal, needed to limit global mean temperature rises to below 1.5°C relative to pre-industrial levels.



This proposal endeavors to build geo-localized, time- dependent and sustainable strategies for the development of bioeconomy in France, identifying synergies between supplying future demands for food, renewable energy, fossil-free materials & chemicals and waste management. It targets residual biomass streams as well as terrestrial biomass species acting as bio- pumps, i.e. allowing for a net transfer of carbon towards the soil carbon pool. I propose a spatially-explicit approach combining consequential Life Cycle Assessment, Energy System Analysis, Process Engineering and Sustainability Economics to determine where, when and in which technologies investments should be made. The bioeconomy strategies proposed will investigate two main pillars.

The first is around carbon farming and the possibility to enhance the potential of the resilient soil organic pool as a net carbon sink, among others through bio-pump species and through determining geo-localized thresholds for the harvest of agricultural residues.

The second pillar focuses on the supply chain and proposes to assess the environmental performance of 300 conversion pathways diverting the biomass from its original use to produce a variety of innovative bioeconomy products (liquid hydrocarbons, proteins, bio-based materials, non-fossil methane gas, etc.) Through these pillars, cutting-edge methodological developments will be performed. This will translate into time-dependant inventories allowing to reflect the fate of carbon, nitrogen and phosphorus flows in the studied pathways and to quantify the advantage of keeping carbon in the technosphere as long as possible. It will further translate into advanced assessment models integrating life cycle assessment and economic sustainability. As a result of this 5-y project, tailored and quantified cost- and environmentally-efficient strategies towards the long-term development of France's bioeconomy will be proposed to French policy makers and stakeholders.

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Philip **SCHULZ**

Home institution National Renewable Energy Laboratory (NREL), USA
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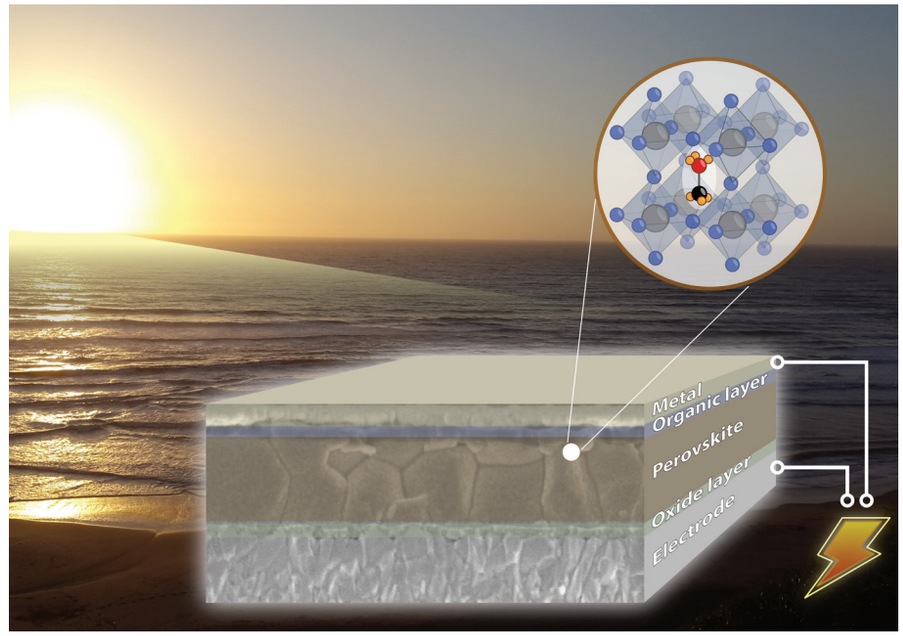
Research

Interfaces and Hybrid Materials for Photovoltaics (InHyMat-PV)

In order for photovoltaics (PV), i.e. the direct conversion of sun light into electricity, to reach terawatt levels as is required for the massive decarbonization of the energy economy, research roadmaps have been drafted, comprising highly efficient, low-cost modules to be realized on an aggressive time scale.

This goal can be reached by the implementation of novel materials that go one step beyond the physical limits of our current silicon-based technology. In the InHyMat-PV research project we explore the fundamental properties of energy materials that can be manufactured inexpensively at high volume, and that are highly efficient and stable. Absorber materials based on the emerging class of hybrid organic metal halide perovskites are on a route to fulfill these needs. Yet, main performance loss mechanisms are linked to improperly designed interfaces in the device.

The research activities of the project are centered on unravelling the effect of interface design on device functionality by a dedicated and integrated film processing and characterization approach. By combining materials discovery and methods development, we pave the way for the next generation of PV modules.



Publications

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Host institutions

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Laboratoire Géosciences Paris-Sud
Saclay (Université Paris-Sud/CNRS)

Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
Toulouse (CNES/CNRS/IRD/UPS)

Laboratoire des écosystèmes et des sociétés en montagne
Grenoble (UGA/INRAE/OSUG)

Institut de Physique du Globe de Paris
Paris (UPC/CNRS)

Institut des Géosciences de l'Environnement
Grenoble (CNRS/INPG/IRD/UGA)

Institut de Chimie de Clermont-Ferrand
Clermont-Ferrand (UCA/CNRS)

Laboratoire d'océanographie et du climat: expérimentations et approches numériques (LOCEAN)
Paris (UMPC/CNRS/MNHN/IRD)

Centre national de recherches météorologiques
Toulouse (CNRS/Météo-France)

Laboratoire d'océanographie
Villefranche-sur-Mer (UPMC/CNRS)

Laboratoire d'aérologie
Toulouse (CNRS/UPS)

Laboratoire Interuniversitaire des Systèmes Atmosphériques
Créteil (Université Paris-Est Créteil/CNRS)

Laboratoire de météorologie dynamique
Paris (CNRS/ENS/Ecole Polytechnique/UPMC)

Institut de Science et d'Ingénierie Supramoléculaire
Strasbourg (UNISTRA/CNRS)

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Moulis (CNRS/Université Paul Sabatier)

Centre d'écologie fonctionnelle et évolutive
Montpellier (CNRS/Université Montpellier/Université P.Valéry/EPHE/SupAgro/INRA/IRD)

Centre population et développement
Paris (IRD/UPC)

Toulouse Biotechnology Institute
Toulouse (INSA/INRA/CNRS)

Institut Photovoltaique d'Ile de France
Paris (SAS IPVF/CNRS/Ecole Polytechnique/ENSCP)

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