60 RESEARCH SUCCESS STORIES FOR A SUSTAINABLE PLANET

PROTECTING THREATENED BIODIVERSITY
FEEDING THE WORLD
PROTECTING THE SEAS AND OCEANS
MANAGING WATER RESOURCES
LAND DEVELOPMENT AND PLANNING
ANTICIPATING CLIMATE CHANGE RISKS

MOBILIZING RESEARCHERS FOR THE CLIMATE AND THE ENVIRONMENT

French Alliance for Environmental Research

NOVEMBER 2015
The global challenge of climate change calls for the strong, broad and open mobilization of the scientific community. The 12 founder members and 16 associate members of AllEnvi represent a community of nearly 20,000 scientists. AllEnvi covers all areas of environmental research and is actively involved in the European Research Area (ERA) and major international initiatives. It therefore brings together a remarkable level of multi-disciplinary and systemic expertise to issues regarding climate change, its causes, its cascading impacts and strategies for combating it.
In a context of global climate change, awareness of limited resources presents major challenges at the international scale. Through the AllEnvi alliance, French environmental research is mobilizing to confront the major societal issues that this raises. The challenges in pictures.

**FOOD SUPPLY**

*Feeding nine billion people by 2050*

Our agricultural and food supply systems contribute to climate change, and are also affected by its direct impacts. New forms of agriculture and feedback rearing could feed the world while promoting biodiversity, reducing greenhouse gases emissions, and even absorbing CO₂.

Researchers are helping farmers produce “more and better” to feed 2 billion extra people by 2050.

Sustainable aquaculture production systems must be reconsidered to meet the growing demand for aquatic products.

Scientist are breeding varieties of cultivated plants that are better adapted for future climate changes.

**WATER AND RESOURCES**

*Ensuring global access to adequate clean water*

Climate change is affecting water cycles, resulting in more frequent droughts and flooding. Water resource management must involve managing usage to ensure access to adequate clean water for all, and protect aquatic ecosystems and prevent risks associated with global warming, such as river flooding and the accumulation of glacier meltwater.

Rising temperatures and water demand for various uses mean that adaptation strategies must be planned in advance.

Maintaining water quality is a crucial challenge in a context of global warming and increasing pollution.

Injecting a tracer to monitor groundwater flow to characterize karst systems.
CLIMATE
Predicting climate change to better adapt

Rising temperatures and changes in rainfall patterns will have an impact on many aspects of the Earth, including soil, air and water. Climate change will thus affect the entire biosphere, including people, and cause much disruption. Climate change is now made; it is urgent that we agree on measures for adaptation and reducing greenhouse gases emissions.
During COP 21, political leaders will attempt to reach a consensus and act to limit greenhouse gas emissions, which are at the root of climate disruption. The Intergovernmental Panel on Climate Change (IPCC) sounded the alarm several years ago, and French research has actively contributed to producing increasingly precise knowledge on the causes, mechanisms and impacts of climate change.

However, the role of scientists is not limited to sounding alarms. They have been working for a long time to develop solutions to mitigate and adapt to climate change in every area. 60 Research Success Stories for a Sustainable Planet bears witness to this effort. The scientific research from AllEnvi members contributes to public policy as well as innovation and value creation. The social and economic benefits from this research are tangible. Sustainable management of water resources, optimization of methane production from bio-waste, improvements to forestry management, and models and decision support systems to help better monitor crops and prevent food crises are just a few concrete examples of the results from research that you will discover in this collection.
Biodiversity, a fundamental issue
Understanding biodiversity’s response to climate change is a fundamental issue, because its properties, ecological functions and adaptive potential are the basis of the values and wealth of societies. For this reason, it is imperative to observe its responses and study its mechanisms.

Bruno David, Chairman of the French Natural History Museum (MNHN)

Focus on food security
Agriculture must contribute to the agenda of solutions to reconcile the fight against climate disruption with food security. It is a major issue for global agricultural research.

François Houiller, CEO of the French Institute for Agricultural Research (INRA)

Jean-Paul Meotti, CEO of IRD (the French institute for research for development)

The South is a priority
Combining the fight against climate change with sustainable development is a top priority for research in developing countries, to reconcile climate change mitigation and adaptation, environmental protection and reducing inequalities.

Jean-Loup Salzmann, Chairman of the French National Centre for Scientific Research (CNRS)

Towards new climate services
Our challenge is to prepare the emergence of climate services, combining knowledge acquired regarding climate and the needs of various categories of users, and offer support to climate change adaptation policies.

Jean-Marc Lacave, CEO of Météo-France (the French meteorological office)

Joint mobilization
Reviewing existing development models, and integrating environmental responsibility and citizenship into all our decisions and actions involves major issues and an ambitious challenge in terms of the training and research associated with climate change in French universities. We are working together to protect our planet and future generations.

Jean-Loup Salzmann, President of the Conference of University Presidents (CPU)

The subsoil: an asset in the face of climate change
Underground technologies serving the energy transition are also used to adapt to climate change: observing and understanding its effects on coastal erosion, groundwater resources, ground shifts... in order to then develop multi-risk analyses leading to new local and regional strategies.

Vincent Lafleche, CEO of the French Geological Survey (BRGM)

Sustainable land management
One of the challenges of climate change is to set countries on the path to sustainable development. The consequences for research are found in the complex changes of scale that this entails.

Jean-Marc Bournigal, CEO of the National Research Institute of Science and Technology for Environment and Agriculture (IRSTEA)

We need low-carbon mobility
Climate change calls for sustainable local development and for development of low-carbon mobility. The complexity of the issues means that a cross-disciplinary partnership approach is needed, covering both technological problems and behavior-and use-related issues.

Jacques Tavernier, Chairman of the Board of the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR)

Science at the outposts
The 21st Conference of Parties on climate change (COP 21) is an opportunity for scientists who are working to understand the mechanisms of climate change, and assess its consequences and impacts, to take centre stage. From social to earth sciences, from ecology to engineering, CNRS is mobilizing its institutes to offer and share their knowledge within the scientific community and with all areas of society.

Alain Fuchs, President of the French National Centre for Scientific Research (CNRS)

Focusing on the analysis of climate change
The research of the CEA and its partners on how the global climate system works and the impact of its changes on the planet contributed to the fifth IPCC report. The CEA also performs research to develop low-carbon energy and improve energy efficiency.

Daniel Verwaerde, General Director of the French Alternative Energies and Atomic Energy Commission (CEA)

Agriculture is directly concerned
Agriculture both contributes to and is impacted by climate change. It is therefore directly concerned in the fight against it. Agricultural research must go beyond studying impacts to also target mitigation and adaptation.

Michel Eddi, CEO of CIRAD (the French agricultural research organization working for development)

Oceans at the heart of the system
Oceans are central to the climate system. In the coming years, one of the challenges is to better understand how species adapt to changes in water masses by migrating towards the poles or by changing their routes.

François Jacq, CEO of the French Research Institute for Exploitation of the Sea (IFREMER)

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In 2013, the French government committed to reaching this target by 2050. Backed by the findings of the IPCC and a mission assigned to climatologist Jean Jouzel by the French Ministry of Ecology, France’s climate change strategy includes major research work and observational infrastructure. It is a joint project led by members of the AllEnvi alliance.

The “Jouzel mission” reports provide regularly updated data on climate change in France, with the fourth report published in 2014. They aim to provide an analysis of climate change in France in the 21st century using changes in precipitation and temperature anomalies. Simulations were produced using two regional climate models implemented at the Météo-France and CNRS National Meteorological Research Centre (CNRM) and the CNRS/ CEA/ Paris Universities Institut Pierre-Simon Laplace (IPSL), in collaboration with the national competence center for industrial safety and environmental protection (NERIS). They are based on three of the four scenarios considered in the latest IPCC report (2013-2016).

What to expect

BY 2021-2050

- An increase in average temperatures of 0.6 to 1.3°C with respect to the baseline average calculated between 1976 and 2000. This rise would be greater in southeastern France in the summer, where increases could reach 1.5 to 2°C.
- An increase in the number of heatwave days in summer, 0 to 5 days across the whole of France, and 5 to 10 days in southeastern France.
- A decrease in the number of unusually cold days in winter, 1 to 4 days over the whole of metropolitan France, and 0 to 5 days in the northeast of the country.

BY 2071-2100

- A significant increase in average temperatures. In particular in southeastern France: this could be well over 5°C higher than the baseline average temperature in the summer.
- An increase in the number of heatwave days in summer, exceeding 20 days for the RCP8.5 scenario (RCP = Representative Concentration Pathway).
- A decrease in extreme cold spells continues through to the end of the century. Between 6 and 10 days fewer than the baseline in southeastern France. It should be more limited in the far south of the country.

OVERSEAS FRANCE

- A temperature increase of 0.7 to 3°C (or even 3.5°C) by 2100.
- A decrease in average precipitation, particularly in the dry season.
- More intense cyclone activity at the beginning of the century according to Volume 1, Chapters 11 and 14 of the 6th IPCC report, in the North-Atlantic basin, along with an increase in frequency of category 4 and 5 cyclones in the North-Atlantic and South-West Pacific basins.

By the end of the century, the overall frequency of tropical cyclones should diminish or stay the same. The average rainfall and mean maximum windspeed associated with tropical cyclones will likely increase.

FOR FURTHER INFORMATION

Climate in France in the 21st Century, Report coordinated by Dr. Jean Jouzel
> www.developpement-durable.gouv.fr/Volume-5- Changements- Climatiques-et-MKm
In 2010, the Ministry of Sustainable Development requested a consultation from the French community of climate sciences to produce a scientific assessment of the climate conditions in France in the 21st century. The report is coordinated, performed by researchers from CNRS, INSU/IPSL, and GIEC, Meteo-France, CNRS, CEA, CETMEF and CNES. All results are available on the DRIAS website
> http://www.drias-climat.fr/accompagnement/section/31

The Sixth National Communication of France to the United Nations Framework Convention on Climate Change (October 2013) presents findings made by France in research and infrastructure.
Observatories, measurement and experimentation sites, models, simulations… A vast and closely knit web stretches around the world and is growing stronger everyday thanks to French, European and worldwide cooperation between researchers. Its aim is to observe, measure, model and understand to better anticipate… An overview in pictures.

**Space-based observations**
-**GCOM-W** A local and global monitoring system for the environment and safety.
-**Dhi** A satellite constellation.

**Ground-based observations**
-**Soil observations**
  - **COSMOS** network: French observation satellites (COSOS) coordinate the local and global observation of soil systems, including CHN. It provides a coordinated response on data.
  - **Soil moisture**
  - **Surface energy balance measurement**
  - **Ground-based climate monitoring**
-**Biological observations**
  - **Biodiversity**
    - **Moss,** lichen, algae, bacteria, fungi
  - **Wildlife**
  - **Habitats**
  - **Human communities**

**Ocean observations**
-**Argo network**
  - **Argo Mission**
  - **Argo France**
  - **Atlantic (PIRATA)**
  - **Argo network**
-**Sea床上 observations**
  - **300m depth**
  - **Ocean currents**
  - **Climate monitoring**

**Airborne observations**
-**Airborne atmospheric observations**
  - **SAFIRE**
  - **IAGOS**
  - **Fluxnet program**
-**Ground-based observations**
  - **Fluxnet**
  - **OBS network**

**Earth observations**
-**Surface observations**
  - **Soil moisture**
  - **Surface energy balance**
  - **Surface temperature**
  - **Surface wind speed**
  - **Surface water temperature**
-**Atmospheric observations**
  - **Atmospheric soundings**
  - **Aircraft observations**
  - **Satellite observations**

**Climate monitoring**
-**Integrated Carbon Observation System (ICOS)**
  - **Integrated Carbon Observing System**
  - **Integrated Carbon Pathway**
  - **Integrated Carbon Observation System**

**Global monitoring**
-**GLOSCOS**
  - **Global Sea Level**
  - **Sea Level**
  - **Ocean Monitoring**
  - **Ocean Currents**

**Climate modeling**
-**Climate models**
  - **GCM**
  - **Regional climate models**
  - **Local climate models**

**Climate change**
-**Climate change**
  - **Attribution**
  - **Impact**
  - **Adaptation**

**Holistic monitoring**
-**Holistic monitoring**
  - **Integrated monitoring**
  - **Holistic observations**
  - **Holistic analysis**

**Climate impacts**
-**Climate impacts**
  - **Natural hazards**
  - **Economic impacts**
  - **Societal impacts**

**Climate adaptation**
-**Climate adaptation**
  - **Mitigation**
  - **Adaptation**
  - **Sustainable development**

**Climate funding**
-**Climate funding**
  - **Climate finance**
  - **Climate investment**
  - **Climate budget**

**Climate education**
-**Climate education**
  - **Climate literacy**
  - **Climate awareness**
  - **Climate activism**

**Climate communication**
-**Climate communication**
  - **Climate information**
  - **Climate education**
  - **Climate engagement**

**Climate governance**
-**Climate governance**
  - **Climate policy**
  - **Climate governance**
  - **Climate regulations**

**Climate translation**
-**Climate translation**
  - **Climate translation**
  - **Climate translation**
  - **Climate translation**
Climate research is highly varied and benefits from the findings in a number of disciplines working in conjunction. The French scientific community is actively working together. Various climate models simulate the exchanges between the atmosphere, ocean, and land surfaces at different resolutions and use different approaches. In particular, a dedicated platform is used to model couplings between ‘ocean and climate’. Here are a few key aspects of this work.

Modelling >>>To understand the workings of the climate system and predict changes, climate models are used to reproduce past variations prior to the impact of human activities, over geological time scales. Another approach consists on increasing the spatial resolution of the models to study the links between global climate and regional and local effects. Modelling can also simulate the future climate. Climate models are coupled with socio-economic models for adaptation to climate change.

Impact studies >>>A consortium of scientists has studied the impact of an overall temperature increase of 2°C in Europe, which is predicted for 2050 or even sooner! According to their analysis the continent would be significantly affected by the rise in temperature. We should expect more severe winters in northeastern Europe (with 20% higher precipitation) and hotter summers (with more severe droughts) around the Mediterranean.

Simulation >>>To predict these changes, researchers perform climate simulations including extreme events. Thanks to ice core research, one of their key discoveries has highlighted the link between CO₂ and temperature. These advances offer new simulations for the 21st century.

ARGO: UNDERSTANDING MARINE CIRCULATION

With 3,000 drifting profiling floats across the world’s oceans, the international ARGO programme measures ocean temperature and salinity in real time. Initial results include an estimate of heat storage by oceans, and insight into the formation of deep waters in polar regions in winter.

METHÉO FRANCE | CNRS | CEA

TRACKING CARBON

Visualizing CO₂ emissions and understanding the carbon cycle are crucial in the attempt to limit future CO₂ emissions to a maximum total of 1,200 billion metric tonnes. In 2013, the Global Carbon Project study showed that global CO₂ emissions are still increasing.

MÉTÉO FRANCE | CNRS | CEA

CLIMATE DATA AT A CLICK

The ‘Drias futures of climate’ website aims to provide everyone with regionalized climate projections: number of unusually hot nights, number of days of frost or heatwaves etc.

MÉTÉO FRANCE | CNRS | CEA

What about sulphate aerosols?

Observation of aerosols, clouds and trace gases in the atmosphere requires the specific equipment and measurements of the ATMO infrastructure. For example, taking into account the reduction in sulphate aerosols in models results in a greater increase in surface solar radiation in Europe and the Mediterranean, and a consequent increase in temperature.

MÉTÉO FRANCE | CNRS | CEA

Methane in ponds

Northern ponds, formed in summer by the surface melting of arctic permafrost, produce large quantities of methane, a powerful greenhouse gas. The smallest ponds are the most active producers!

MÉTÉO FRANCE | CNRS | CEA

Ice core drilling

The France-Italian Concordia Research Station is one of the three permanent Antarctic stations. As part of the EPICA programme, deep ice core drilling provides insights into past climates going back 800,000 years.

MÉTÉO FRANCE | CNRS | CEA

Variability of water masses

The OVIDE project observes the currents and properties of water masses of the North Atlantic subpolar gyre. Ocean-based observations and modelling studies are performed in Greenland and Portugal.

MÉTÉO FRANCE | CNRS | CEA

A quick overview of current knowledge on the climate and its changes, the current state of research, diagnostics, and observations via a few key results...
Understanding the response mechanisms of biodiversity to climate change makes it possible to develop adaptation strategies and assess their effects on the environment and society.

Pressure from human activities is threatening biological diversity and hindering its ability to evolve and adapt, resulting in serious consequences including impacts on the biodiversity and ecosystem services used by people. One of the key challenges of adapting to climate change is the ability of ecosystems to maintain their resilience. The same applies to human societies that depend on ecosystem services.

To anticipate and target actions, biodiversity needs to be defined and understood in terms of the way it functions and the factors affecting how it evolves. The past response mechanisms of biodiversity to climate change provide indicators for current ecosystems. Characterizing the current dynamics of land, aquatic and marine ecosystems and sensitive, island and mountain ecosystems affected by global climate change provides a basis for understanding and improving the resilience of ecosystems. One of the main goals of the research is to develop future scenarios for biodiversity.

Biodiversity research provides the insight needed to anticipate, guide and manage changes that interact with human societies, and make collective decisions that lead to sustainable systems within the context of global climate change.
**FOCUS**

**MAPPING CORAL REEFS**

**PREVENTING BLEACHING**

**WHAT**

**PROTECTING CORAL: THREATENED BY GLOBAL WARMING**

In the face of growing and alarming coral reef bleaching, researchers have mapped zones at risk according to rises in temperature.

Corals are among the first animals to have populated the seas and oceans.

Coral bleaching is an extremely alarming phenomenon. It is a spectacular consequence of rising atmospheric temperatures and one of the main threats to coral reefs. In the 1980s, from the Atlantic Ocean and Caribbean Sea to the Pacific and Indian Oceans and the Arabian Peninsula and Red Sea, almost all the world’s major coral regions began to be affected by this process, which has deteriorated since the 1990s, transforming numerous reefs.

Coral dies at temperatures over 30°C. Bleaching results from the loss of symbiotic algae within the tissues of coral polyps. It is a stress phenomenon caused by a rise in ocean temperatures, generally above 30°C over periods of several weeks, which can cause the animal to die. By 2040, three-quarters of the world’s coral reefs will be affected by coral bleaching at least once a year if nothing is done to stop the rise of atmospheric temperatures. The scientific community fears that all reefs will be affected by 2056.

To combat the predicted coral reef loss, French and American researchers have mapped out zones at risk using the latest climate forecasts produced by the Intergovernmental Panel on Climate Change (IPCC).

“This phenomenon occurs when the algae which feeds on the coral and gives it its colour is expelled when water temperatures rise above 30°C for two to four consecutive weeks,” explains Serge Planes, co-author of a paper published in the journal *Nature Climate Change*. Depending on the species, bleaching causes coral to die in 15 to 60% of cases.

**France is directly affected**

To model rising ocean temperatures and predict bleaching events, researchers used the most recent IPCC projections, which predict a 1 to 3°C rise in atmospheric temperatures by 2050.

Coral reefs off northwest Australia, the Philippines and Papua New Guinea are the most fragile and will be affected by annual bleaching events as early as 2025-2030. Less fragile zones include the Great Barrier Reef in Australia and French Polynesia, which are not likely to be affected before 2056. Nearly 4% of the world’s surface is made up of coral reefs spread across its oceans. It should not be forgotten that France is directly affected.

It is difficult to predict how coral will adapt to the change in current equilibriums,” explains Serge Planes. “Reefs will change and tomorrow’s dominant species will probably not be the same as today’s.”

In fact, recent research predicts that the coral species most resistant to rising temperatures, with the highest growth rate and greatest longevity will fare the best. The marine ecosystem will therefore metabolise and scientists are not sure whether it will be able to sustain the species that inhabit it. The mysteries of the seas and ocean depths remain.

Land use planning with Green and Blue Corridors

What can be done to facilitate species movement in their vital areas despite climate change? This is the goal of the Green and Blue Corridors projects that have been established on different regions of France as part of the Grenelle de l’Environnement initiative and the strategy to create protected areas in France. “Ecological corridors” were identified for open thermophilic environments and a number of research projects are underway to better understand the role of protected areas in the face of climate change.

Better understanding the adaptation of species to climate change

The various forms of global change affect marine and continental ecosystems differently. Researchers are working on the effects of exposing the larvae of certain fish (sole and sea bass) to warmer and less oxygenated environments. Once these larvae have grown, the adults show major physiological changes. The goal is to understand and predict how species adapt to warmer waters.

CLIMIT: protecting butterfly habitats

The European project CLIMate change Impacts on Insects and their Mitigation (CLIMIT) underlines the importance of creating and preserving grasslands for insects and particularly butterflies. Habitat heterogeneity makes it easier for species to adapt. These results have been used to make recommendations to policy makers and other stakeholders (managers, environmental agencies, etc.).

Receding glaciers = 40% of aquatic fauna at risk

As thawing continues to increase globally, the diversity of mountain ecosystems is threatened. Researchers have found that if glaciers were to disappear, it would result in the extinction of 10 to 40% of aquatic fauna, depending on the region.

Ecologists studied the biodiversity of glacier water streams in the Andes, at 3,500 to 5,000 metres. If the species living in these extreme environments were to disappear, some of the world’s most unique ecosystems would be lost.

A major biological invasion in 2100? Biological invasions (the arrival of a new plant or animal species in a place far from its natural habitat) are one of the greatest threats to biodiversity. The International Union for Conservation of Nature has even created a list of the world’s worst invasive Alien Species’, including the Asian hornet, the tiger mosquito, cypripedium and ragweed. One scientific team recently showed that climate change and land-use changes (deforestation, urban sprawl, agriculture, etc.) could potentially have devastating effects on the spatial distribution of these invasive species by 2100.

Protecting coral threatened by global warming

In the face of growing and alarming coral reef bleaching, researchers have mapped zones at risk according to rises in temperature.

It is predicted that by 2040, three-quarters of the world’s coral reefs will be affected by coral bleaching at least once a year if nothing is done to stop the rise of atmospheric temperatures. By 2050, nearly 4% of the world’s surface is made up of coral reefs spread across its oceans. It should not be forgotten that France is directly affected.

To combat the predicted coral reef loss, researchers have mapped zones at risk using the latest climate forecasts produced by the Intergovernmental Panel on Climate Change (IPCC). This phenomenon occurs when the algae which feeds on the coral and gives it its colour is expelled when water temperatures rise above 30°C for two to four consecutive weeks.”

In fact, recent research predicts that the coral species most resistant to rising temperatures, with the highest growth rate and greatest longevity will fare the best. The marine ecosystem will therefore metabolise and scientists are not sure whether it will be able to sustain the species that inhabit it. The mysteries of the seas and ocean depths remain.
Climate change has a major effect on agricultural production. The global organization of food systems is affected. Solutions exist both for adapting consumption and using more responsible ways of producing more food.

Agromonde foresight study examining global food and farming systems in the years leading up to 2050 looked at the impact of a 30% reduction in meat consumption and a reduction in waste and spoilage. Consumer behaviour appeared as a key factor. The second goal is to rethink production methods, adapt to biotic and abiotic stresses resulting from climate change, reduce greenhouse gases emissions, and contribute to carbon sequestration. For instance, to achieve this, research work quantifies the uncertainties on future crop and grassland yields. Other studies examine the genetic adaptation of cattle in the Mediterranean region. Measures are proposed to reduce the greenhouse gases emissions of French agriculture. This includes reducing fertilizer use, selecting different varieties, farming with nitrogen-free fertilizers and reducing ruminate methane emissions. Similarly, international research is striving to design and assess practices that are more productive, reduce greenhouse gases emissions and contribute to carbon sequestration.
**BEFORE CROP MONITORING TO AVOID FOOD CRISES**

Since the 1980s, researchers have been developing a computer model to simulate and monitor annual crops, in particular to estimate the impact of a climate scenario and predict crop yields. The latest version of the SARRA-H model is specifically adapted to the global issues of climate change and food security, and seems to have proven its effectiveness. Furthermore, its latest version has been available in three languages (French, English and Portuguese) since 2014. This wide-ranging work has led to various applications on the subject in France’s partner countries.

**Application in 17 West African countries**
SARRA-H has recently integrated new improvements, specific to the issues of an early warning system for West Africa in order to avert food crises. On the basis of this model, teams of researchers can provide hydric monitoring, the state of crops and yield forecasts.

Since 2013, AGRHYMET, in partnership with the French teams and with the support of the World Meteorological Organization (WMO), has offered a series of training workshops on the new version of SARRA-H. No fewer than 17 countries in West Africa are involved. In Brazil, the new version of SARRA-H has now been applied to the Tracking Oil Spills & Coastal Awareness (TOSCA) project, in association with direct sowing and soybean crops. It has also been used in the context of the European project Stimulating Innovation for Global Monitoring of Agriculture and its impact on the environment (SIGMA). The Brazilian government used the model to implement public policy on credit management for farmers. In place for 20 years, this policy has doubled production and generated considerable savings for the country.

**Analyzing the impact of climate on cereal growth**
SARRA-H is a powerful tool for simulating crop growth, and the upgraded version of the SARRA software suite can be used to estimate the impact of a climate scenario on annual crops. SARRA-H is more specifically adapted to analyzing the impact of climate on the growth of dry cereals, such as millet, sorghum, corn and rainfed rice, cultivated in West Africa, along with soybeans. To achieve this, various processes (soil water balance, potential and actual evaporation and transpiration, phenology, potential assimilation and assimilation under water stress, maintenance respiration, and biomass distribution) are used to simulate potential crop yield, giving priority to simple robust approaches.

Having demonstrated its strong performance in this area, the software has been calibrated using a series of local, modern varieties of millet, sorghum and corn. Tests are conducted in controlled environments. To assess the predictive quality of the model, agronomic monitoring was performed many times over several years with subsistence farmers. The sites selected, in Niger, Senegal, Mali and Burkina Faso, are impacted by both agricultural practices and climate.

Finally, a series of scenarios representing agricultural practices was produced. Different crop varieties were also highlighted. For example, specific studies were conducted on local cultivars of sorghums and millets, which are notable for their strong sensitivity to photoperiod, and led to a module integrated into the model. On the technical level, teams explain that SARRA-H is “a modular deterministic model of crop growth from the plot to regional scale.” It integrates three major processes into a single daily cycle: water balance, carbon balance (biomass) and vegetative phenoology.

**Objectives: estimating and forecasting biomass and potential yield**
Thanks to their network of partners, in the North and especially in the South, scientific teams representing ...
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**AT A GLANCE**

The coffee genome has finally been sequenced...

An international consortium coordinated by a French team has just published the first reference sequence for the coffee plant genome, a plant of primary economic importance. *Coffea canephora,* better known as robusta, was chosen for its diploid genome (2 x 11 chromosomes), while *Coffea arabica,* the other cultivated species, is a tetraploid hybrid (4 x 11 chromosomes) of robusta and *Coffea eugenioides,* and therefore more complex to sequence. By combining several sequencing technologies, the researchers deciphered the 710 million base pairs of its DNA and identified over 25,000 genes. This identification of agronomic interest should facilitate the selection or creation of varieties that are more resistant to environmental constraints and pests (such as insects, fungi and viruses).

**Rice is not afraid of heat!**

By measuring rice spikelet temperatures, researchers are studying the mechanisms developed by the plant so that it can flower despite the heat. This knowledge is integrated into models, meaning that growing practices can be adjusted and new varieties bred.

Coffee plants adapting to multiple stresses

In Latin America, French researchers are analyzing coffee-plant adaptation to combinations of stress (such as drought, diseases and nematode attacks), with a view to offering new varieties and cropping methods suitable for agroforestry.

**LCR to better assess environmental impacts on production**

Life cycle analysis (LCA) assesses the environmental impacts throughout a production system, from raw material extraction to a product's end of life. The ACR-Cirad© database uses this approach and covers the entire life cycle of a product: from raw material extraction to production, consumption and waste, for products from developing countries (citrus fruit, cotton, tomatoes, palm oil, coffee, rice, cassava, jatropha and beef).

Atlantic bluefin tuna: a fragile giant in recovery

Atlantic bluefin tuna is a mysterious species that fascinates scientists and constitutes an important field of study. As a shared resource with high market value, it is fished by around 20 countries. French researchers studying the ecology of bluefin tuna have worked on the history of its overfishing between 1990 and 2000, and produced management models for stock recovery, from 2007 to 2022, for a species that is particularly sensitive to the thermal environment.

Gaining a better understanding of the impact of climate change with rubber plantations

In Thailand, French researchers and their partners are measuring water and carbon exchanges between rubber plantations and the atmosphere using flux observation towers. Understanding the behaviour of these plantations will help test various climate change scenarios.

Rural African populations in tough conditions

To understand how Sub-Saharan African populations perceive and adapt to climate variability, sociologists, anthropologists, demographers, climatologists, economists, geographers and agronomists performed field surveys in Senegal, Mali, Niger and Benin, over four years as part of the Environmental and Social Changes in Africa (ESCAPE) project. The results confirm significant warming in West Africa over the last century, re-greening in the Sahel region since the late 1990s and an increase in extreme weather events. While rural populations have so far succeeded in adapting, projections show that agriculture will be severely constrained if warming reaches +2°C. These conditions could jeopardize the ability of local populations to adapt.

**Installation of sensors to monitor temperature and environment in the vineyard to study the physical environment of the plant in a Bordeaux vineyard.**

**Coffee researchers are testing new varieties that ripen later and are more resistant to drought and heat on experimental vineyards in Alsace, Aquitaine and Languedoc-Roussillon.**

**Wineries are their laboratories. They test different techniques to reduce the alcohol content or adjust the pH of grape juice etc. Finally, they survey wine producers to better anticipate the reactions of professionals in the face of climate change and necessary adaptations.**

**Where do consumers stand in this? They have not been left out. Their taste for new wines and their willingness to purchase are analyzed in detail. This should be expected given that France is the top wine consuming country on the planet and that wine is France's second-ranked export.**

**Installation of a flow and sampling system into a high-throughput sequencer (Illumina) in the Genoscope sequencing room.**

**Installation of sensors in a Bordeaux vineyard to study the physical environment of the plant.**

**Rice is not afraid of heat! By measuring rice spikelet temperatures, researchers are studying the mechanisms developed by the plant so that it can flower despite the heat. This knowledge is integrated into models, meaning that growing practices can be adjusted and new varieties bred.**

**Coffee plants adapting to multiple stresses In Latin America, French researchers are analyzing coffee-plant adaptation to combinations of stress (such as drought, diseases and nematode attacks), with a view to offering new varieties and cropping methods suitable for agroforestry.**

**LCR to better assess environmental impacts on production Life cycle analysis (LCA) assesses the environmental impacts throughout a production system, from raw material extraction to a product’s end of life. The ACR-Cirad© database uses this approach and covers the entire life cycle of a product: from raw material extraction to production, consumption and waste, for products from developing countries (citrus fruit, cotton, tomatoes, palm oil, coffee, rice, cassava, jatropha and beef).**

**Atlantic bluefin tuna: a fragile giant in recovery Atlantic bluefin tuna is a mysterious species that fascinates scientists and constitutes an important field of study. As a shared resource with high market value, it is fished by around 20 countries. French researchers studying the ecology of bluefin tuna have worked on the history of its overfishing between 1990 and 2000, and produced management models for stock recovery, from 2007 to 2022, for a species that is particularly sensitive to the thermal environment.**

**Gaining a better understanding of the impact of climate change with rubber plantations In Thailand, French researchers and their partners are measuring water and carbon exchanges between rubber plantations and the atmosphere using flux observation towers. Understanding the behaviour of these plantations will help test various climate change scenarios.**

**Rural African populations in tough conditions To understand how Sub-Saharan African populations perceive and adapt to climate variability, sociologists, anthropologists, demographers, climatologists, economists, geographers and agronomists performed field surveys in Senegal, Mali, Niger and Benin, over four years as part of the Environmental and Social Changes in Africa (ESCAPE) project. The results confirm significant warming in West Africa over the last century, re-greening in the Sahel region since the late 1990s and an increase in extreme weather events. While rural populations have so far succeeded in adapting, projections show that agriculture will be severely constrained if warming reaches +2°C. These conditions could jeopardize the ability of local populations to adapt.**

**Terraced rice paddies after harvest in a village near Quan, in southeast China.**
The sheer size and slow reaction of the sea to phenomena, presents a major scientific challenge in the context of global warming. While it is an essential component of the climate system, the sea responds slowly to warming, with very specific properties compared with the other components (the atmosphere, the earth’s surface and the cryosphere). Furthermore, current climate changes have not been seen in thousands of years. The sea presents a specific challenge, with consequences on changes in the chain of life, such as ocean acidification (see opposite). Its negative impact on biodiversity and economic activities such as fishing worries scientists. The latest IPCC report confirms that many marine species will migrate north due to rising temperatures. This movement will have an impact on fishing in tropical regions, with reduced production potential and greater vulnerability for coastal areas. Specialists admit that: “Understanding the impacts of warming on sea water is a highly complex science.” French research is hard at work on these aspects. Observation is essential, especially as it is generally performed in difficult to access areas and in deep waters. The combination of local and space-based observation will be a key for future research.

Ocean pH levels have dropped by 30% since the start of the industrial revolution. This phenomenon disturbs the entire marine ecosystem and could have devastating effects on many marine species.

FUTURE CHALLENGES
Ocean acidification is one of the little-known consequences of human activities. Scientists are now beginning to understand its effects better. Acidification is directly associated with the increase in the quantity of carbon dioxide in water, and is induced by excessive greenhouse gases emissions, leading to a gradual drop in ocean pH levels. Mean ocean acidity is set to triple by 2100!

OCEANACIDIFICATION
Acidification reduces the size of marine shellfish
An international study coordinated by a French team, in association with Italian researchers, demonstrated that the size reduction observed in certain marine organisms during past mass-extinction crises could be the consequence of ocean acidification. This reduction would have allowed them to survive in the presence of high CO2 levels, a phenomenon that could recur in the future as a result of climate change.

Are Marine Protected Areas still effective?
The Mediterranean has over a hundred Marine Protected Areas (MPA) to protect marine biodiversity. Population connectivity, in particular provided by larval dispersal due to currents, is essential to the effectiveness of these populations. For example, the dusky grouper is a notable Mediterranean species that is heavily fished and whose survival depends on Marine Protected Areas. Researchers have shown that Mediterranean MPAs are far from providing a true connected network. The average distance between MPAs is 1,032km, while the average dispersal distance of dusky grouper larva is only 120km, which means that many local populations are totally isolated. The phenomenon is even more disturbing given that climate change (based on an assumption of a 2.8°C temperature increase by the end of the 21st century) will affect the degree of connectivity of Mediterranean fish populations by reducing larval dispersal distance by 10%.

Phytoplankton: adapting fishing strategies
For the first time, researchers have assessed the ability of numerical models to predict long-term changes in a biological parameter at the bottom of the marine food chain: the primary production of phytoplankton. These natural variations could be predicted several years in advance in the equatorial Pacific. This paves the way for potential rational fishing strategies that cover several years.

At a glance

Ocean acidification is one of the little-known consequences of human activities. Scientists are now beginning to understand its effects better. Acidification is directly associated with the increase in the quantity of carbon dioxide in water, and is induced by excessive greenhouse gases emissions, leading to a gradual drop in ocean pH levels. Mean ocean acidity is set to triple by 2100!
MANAGING WATER RESOURCES

Climate change will increase water scarcity and quality issues: high and low flows, competition between uses.

Climate change and the expected increase in extreme weather events will have an impact on the seasonal and geographical distribution of water resources, on the state and functions of aquatic environments, and on natural risks (flooding, drought, avalanches, soil erosion, landslides etc.). All economic activities will be affected, including agriculture. The quality of the resource and aquatic life will also change due to increased pollution and the reaction of ecosystems to rising temperatures and decreases in flow rates in particular.

Our objective is therefore to gain a better understanding of processes to reduce our vulnerability to these changes, in particular by proposing new, more frugal technologies and developing new behaviors. Tensions will continue to grow between different water uses, and between objectives for protecting the resource and natural environments and those associated with economic, social, energy, agriculture, etc. The goal is to conserve water and share it better in the context of climate change. It therefore becomes vital to rely on multi-disciplinary, integrated research in order to anticipate and act.
**GROUNDWATER SEEN FROM SPACE**

*WHY!* IMPROVING OUR UNDERSTANDING OF AQUIFERS AND THEIR IMPACT ON CLIMATE

Almost all fresh water - 96% of it - is beneath our feet. However, these invisible reservoirs are difficult to study. Researchers have developed a method to map aquifers ... from space. This is being applied to the Amazon rainforest ecosystem.

**HOW** do we map the water beneath our feet? The answer is from space! While groundwater represents 96% of fresh water on the planet, aquifers are by definition underground and therefore have been very difficult for scientists to study. The specific geographical location of certain aquifers also makes it difficult to observe them using traditional methods.

A major advance has been made for wet regions like the Amazon rainforest, where French researchers, with Brazilian partners, have succeeded in developing a new method for measuring groundwater tables.

Using images from the European ENVIRONMENT ATELIER ENVISAT satellite, scientists have produced the first maps of the Amazon aquifers beneath the largest rivers in the world, the Amazon and the Rio Negro. This Earth observation satellite was launched by the European Space Agency in 2002, to continuously measure environmental parameters related to the atmosphere, the ocean, land masses and ice at various scales.

The maps produced show groundwater tables during the low-water periods from 2003 to 2008. They also explain how the aquifer responded to droughts, such as the one that occurred in 2005. The aim is to better characterize its role in the Amazon climate and ecosystem.

**MIGHTY AMAZON**

The Amazonian forest, the world's most extensive tropical rainforest, has an average temperature of 26°C all year round. This vast reservoir of biodiversity is also home to the world's greatest river, the Amazon, which is some 6,300 km long from its source in Peru to the Atlantic Ocean into which it flows. During the rainy season, between December and May, it can attain a width of 20 km and carry almost 20% of the planet’s fresh water.

Although its size and geographical location make it hard to study, Amazon groundwater plays a vital role in this rich alluvial ecosystem. It provides rivers, lakes, surface waters and flood plains with an abundant supply of water during the drier seasons, meaning that plants suffer less water stress.

**IMPROVING OUR UNDERSTANDING OF AQUIFERS**

Scientists have developed a method to map aquifers using satellite altimetry measurements. This technique has only been used for a few years, to observe continental surface water. Several years of work were needed to calibrate and validate data that had been collected. Over 500 rivers, lakes and flooded areas in the Amazon Basin were thus scrutinized to specifically determine altitudes and level variations.

**No fewer than 491 measurement stations**

Using the concepts of interaction between underground and surface water and altimetry data gathered by the ENVISAT satellite, scientists were “able to assess groundwater table topography during low-water periods in the alluvial plain of the central Amazon.”

These measurements required no less than 491 altimetry stations positioned on the water’s surface, providing unprecedented coverage to match the vastness of the Amazon Basin. As a result, groundwater table maps have been developed with a resolution of 50 to 100 km.

**Aquifers finally revealed**

This major project provides a better understanding of large-scale groundwater hydrological processes. This is essential environmental data as it directly concerns the water cycle, the carbon cycle and maintenance of biodiversity in the Amazon. Groundwater has lost its mystery!

**Mapping from space**

Mapping from space is a unique method already used on oceans and now applied to the Amazon. The research team developed a method for studying aquifers using satellite altimetry measurements. This technique has only been used for a few years, to observe continental surface water. Several years of work were needed to calibrate and validate data that had been collected. Over 500 rivers, lakes and flooded areas in the Amazon Basin were thus scrutinized to specifically determine altitudes and level variations.

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**There is a significant ‘memory effect’ in the aquifer that could have a significant impact on climate.**

The water table can remember!

The 2005 drought had a significant impact on most of the study area, because, according to scientific observations, the low-water level suddenly dropped. Over the months, this level rose little by little from North to South. It only recovered its mean value between 2007 and 2008.

This revealed to researchers a significant ‘memory effect’ in the aquifier. It could even have a significant impact on climate. The consequences of unusually low water levels are well known: a reduction in evapotranspiration, reduced air humidity and an ultimate decrease in rainfall.

Satellite mapping of aquifers has proved to be an essential source of data. This method is a major advance for hydrology studies and reveals the spatial and temporal structure of Amazonian groundwater for the first time. This major project provides a better understanding of large-scale underground hydrological processes. This is essential environmental data as it directly concerns the water cycle, the carbon cycle and maintenance of biodiversity in the Amazon. Groundwater has lost its mystery!

**LOW-WATER GROUNDWATER TABLE FOR THE CENTRAL AMAZONIAN CORRIDOR**

This map shows the mean groundwater table during the driest periods of the year between 2003 and 2008.

**Key**

- **Main rivers**
- **Virtual stations based on space altimetry**

**Level of the groundwater table above the geoid (m)**

**Values**

- **High: 75**
- **Low: 0**

**Table in the Central Amazon by satellite altimetry**

IRRIGATION: NEW TECHNOLOGIES FOR MORE EFFECTIVE AND OPTIMIZED USE

WHAT

Miticating water shortages in agriculture

Irrigation of food crops and green spaces consumes large quantities of water. To reduce its impact, researchers and engineers are working to develop new technologies, in particular a system for treating and reusing wastewater. Here is an overview.

T

here are many innovative irrigation techniques and practices to reduce pressure on water resources. French scientific and R&D teams are working to improve existing technologies and develop new more economical systems. For example, subsurface drip irrigation (SDI) is a well-known technique that has already been subject to numerous innovations. SDI is an attractive solution for most countries faced with a shortage of "blue gold", due to its efficacy. As an increasing number of French regions face water restrictions, it is becoming a viable option for irrigating large-scale crops.

Subsurface drip irrigation

Subsurface drip irrigation first appeared in the United States over 20 years ago and is suitable for potatoes, fruit trees, wheat and vines. It consists of burying localized irrigation lines over small surface areas, which then release small quantities of water to plants. Its main drawback is that tubing has been found to be vulnerable to clogging and root intrusion. The appearance of new, more effective materials have enabled it to be applied to large-scale crops, such as corn, under certain conditions.

For large-scale crops, specialists recommend the use of irrigation lines fitted with drippers 30 to 40cm apart and buried 30cm deep, i.e. below ploughing depth. Each dripper delivers water at an even nominal flowrate. Anti-siphon and anti-root systems prevent soil particle and root intrusion.

Scientists stress one of the advantages of drip irrigation compared with classic spray irrigation: "With no wind effects and with effective automatic regulation, SDI uses 20% less water (under the climatic conditions of Montpellier) i.e. one or two irrigation sprinkler lines. However, during a dry spring, wind erosion can be a problem and require supplementary spraying."

Wastewater recycling: a promising system in the context of climate change.

Another avenue being explored concerns the recycling of wastewater to irrigate crops. This is the idea of the REUSE project for treated wastewater reuse. France has recently adopted suitable legislation that should pave the way for a promising system to mitigate water shortages in agriculture in the context of climate change.

Implemented as part of the New process for Optimizing Wastewater Reuse from Mauguio to the Mediterranean Area (NOWWMA) project, running from 2012 to 2015, REUSE is based on suitable treatment for the distribution of wastewater to plants. This R&D project led to the development of a pilot scheme tested in Mauguio, in the Camargue, which was then extended to the entire Mediterranean Basin.

Wastewater for farming and roadways

Assessing aerosol drift using a spray system and water with a coloring agent added to simulate wastewater.

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Determined HIV protease resistance to antiretroviral therapies.

EMERGING INFECTIOUS DISEASES

PREVENTING EMERGING INFECTIOUS DISEASES

Dangerous links exist between climate and emerging infectious diseases. Global changes risk directly or indirectly affecting human health via emerging or re-emerging infectious diseases.

While it is difficult to establish a direct link between climate variations and global changes in infectious diseases, new illnesses are appearing, caused by previously unknown bacterial or viral agents or by changes to known agents under the effect of climate variations. These are emerging or re-emerging infectious diseases, such as leishmaniasis, West Nile virus, etc. According to the World Health Organization (WHO), infectious diseases cause a third of deaths worldwide, mainly in developing countries.

Several parameters could be responsible for the increased spread of pathogens and their hosts. Climate change modifies the temperature and humidity conditions of natural environments, and the distribution areas, abundance, behaviour, biological cycles and life history characteristics of these pathogens and their hosts. These effects are still poorly explained. Research needs to develop an understanding of long-term spatial and temporal changes in these phenomena.
EMERGING INFECTIOUS DISEASES

FOCUS

AVIAN MALARIA
PREDICTING INFECTION

WHAT

AVIAN MALARIA COULD AFFECT BRITTANY AND NORTHERN FRANCE

The map of the projected spread of avian malaria into the regions where it is currently rare, suggests that France will not be spared. What role does climate change play in the emergence of this infection risk?

WHAT

infection risk?

The disease will spread to regions that have been relatively spared so far.

Using field sampling, an international study involving several French researchers, produced a model that aims to predict the way in which global warming will affect avian malaria in France. The results, published in Scientific Reports, show that within a few decades rising temperatures will promote the spread of the disease into regions where it is currently seldom encountered, such as Brittany and the northern part of the country.

1,750 birds examined in 24 locations

It is difficult to estimate the spread of infectious diseases because many health measures are implemented to limit their emergence and expansion. In the face of the increased risk of contracting avian malaria predicted by various climate scenarios, the disease is actually declining in the areas where it is endemic, and has been for a few decades.

The international study in question therefore focuses itself on socio-economic factors by focusing only on pathogens in wild fauna, in this case the avian malaria parasite in house sparrows. The pathogen is a protozoan, of the genus Plasmodium, similar to that which causes human malaria.

As infected mosquitoes pass the illness to birds, the network of amateur bird ringers from the French Research Centre on Biology of Bird Populations (CRBPO) examined 1,750 birds in 24 locations in France.

To attribute the variability of avian malaria prevalence (proportion of birds infected) to environmental factors, researchers focused on temperature, precipitation and altitude data for each of the sites studied.

Predicted prevalence of the disease in 2050 and 2080

Brittany, Normandy and Nord-Pas-de-Calais are currently little affected by avian malaria, but by 2050 they will also be hit by this disease. The authors of the study in question analyzed several climate factors, such as daily temperature variations, to produce a model to predict the prevalence of the infection in 2050 and 2080. Climate change accounts for 83% of the spread of infection risks to the populations of these island countries and territories. Collaboration is essential for deploying tools to anticipate emerging health issues.

WHAT

INFECTION DISEASES:
WHAT ARE THE FUTURE RISKS?

Anticipating climate-related outbreaks of dengue fever

A scientific study performed in New Caledonia has demonstrated the key role that climate plays in epidemic dynamics. French researchers and their New Caledonian counterparts analyzed epidemiological and climate data, gathered in Nouméa over 40 years. They revealed the correlation between specific climate conditions and the appearance of dengue fever outbreaks. This work has produced explanatory and predictive statistical models for viral episodes.

While the New Caledonian public health authorities have already integrated these tools into their decision-making strategies, a similar approach is being developed in other South Pacific countries, with a new collaborative regional program.

What is the effect of environmental change on the emergence of vector-borne diseases (carried by mosquitoes, ticks, etc.)? As part of the EDENext project (Biology and control of vector-borne infections in Europe), French researchers have organized vector-specific working groups.

Ticks: what is the transmission risk for new pathogens, such as Crimean–Congo hemorrhagic fever virus? mosquito-borne viruses, such as Aedes albopictus, and the risk of transmission of the dengue fever and chikungunya viruses, or Culex species and the risk of transmission of West Nile virus. Phlebotomine sand flies: what is the transmission risk for the leishmaniasis pathogen, or the viruses responsible for various kinds of encephalitis in several Mediterranean countries? Rodents and insectivores, are vectors for hantaviruses, orthopoxviruses and the lymphocytic choriomeningitis virus in Europe.

50 RESEARCH SUCCESS STORIES FOR A SUSTAINABLE PLANET
Globally, 13 million hectares of forest have been lost each year for the past 10 years! It is vital to strengthen and better manage our forests.

Forests are an important ecosystem as they represent 30% of the earth’s land mass. They act as a ‘carbon sink’. They also contribute to rainfall and can help prevent drought. The first aim is to combat deforestation. In the tropics, and more generally in developing countries, deforestation is becoming increasingly widespread, despite the fact that it is slowing down in some countries. This has many consequences, including the extinction of fauna and flora, significant carbon emissions due to wood burning, soil erosion and water pollution.

France has more forests today than a century ago and European forests are faring relatively well. However, economic development of the wood sector must be better supported. The second aim is to conserve forests and help them adapt to climate change. Through improved management of forest and forest soils, and better integration within different ecosystems (alternating farmland, woodland and pasture), research focuses on the assessment of forest functions and services, their protection, adaptation and management.

Fire, fire!

Forest fires. The FUME project (Forest Under Climate, Social and Economic Changes) has created tools to better manage future forest fires. In a context of climate change, social and economic change, FUME seeks to improve forest fire fighting and prevention policies. Risk zone maps have been drawn up for Europe and the Mediterranean basin, on a regional and overall scale, according to climate change and changes to land use and human activities. These tools and long-term models are extremely useful for policy makers for the implementation of land use planning that takes into account the risk of fire.

Resilience. The second aim of the FUME project is to increase resilience to future threats. One way of achieving this is by promoting mixed stands, which are better suited to facing extreme climate conditions. Researchers also recommend planting techniques that use the cover of existing vegetation (nurse plants) to encourage the growth of more diverse vegetation. Experimental nurse plant plots have been created in Saint-Mitre-les-Remparts.

To what extent can forests adapt?

The FORADAPT project was launched in 2013 and will run until 2016 with the aim of assessing climate change adaptation strategies for forests. It seeks to broaden and compile current knowledge of forest adaptation mechanisms (phenotypic plasticity, migration, genetic variation, community rearrangement and forest management) and improve existing databases. It also involves identifying adaptation strategies to ensure the long-term future of the ecosystem services provided by forests. For this, FORADAPT has created the first network of scientists in this field where members pool knowledge and data.

90% of French Guiana is covered by Amazonian rainforest and the country is home to over 1,500 tree species. Although deforestation is only a minor issue, this exceptional natural heritage is threatened by climate change.

French Guiana’s tropical rainforests host a wealth of exceptional biodiversity, but are threatened, not by deforestation, fragmentation or deterioration of the landscape, but by severe climate events such as repeated droughts and ever-rising temperatures. The Amazonian rainforest is vital to overall planetary equilibrium, providing water and climate regulation, carbon sequestration and wood production. French researchers launched the CLIMFOR project to better understand current threats. Its aim is to explore the consequences of climate change on four ‘ecosystem services’ in the region: plant diversity, functional diversity, carbon sequestration and wood resources. Some 95% of the population live in northern French Guiana, where there is no baseline map for ecosystem services. Thanks to new modelling techniques, CLIMFOR used meteorological data, forest inventories and functional traits to make projections according to various climate scenarios.

Early results show a significant ‘water stress’ effect, particularly for wood regeneration, with negative consequences on the growth of various commercial species. Researchers also explain that, “trees tend to renew their leaves at the end of the dry season by drawing on their reserves for optimal photosynthetic efficiency at the start of the rainy season”. This seasonal pattern of the forest may be threatened by a more intense dry season.

Mapping areas in need of protection

Scientists have successfully produced so-called ‘irreplaceability’ maps that identify priority protection areas. The results suggest that carbon stores in the forests of French Guiana are sufficiently uniform for biodiversity to be the major goal across all protection areas. These results have proven useful to direct forest management practices.

To what extent can forests adapt?
CHANGING OUR ENERGY NEEDS

Climate change means that we urgently need an energy revolution. Within just a few decades, it will be vital both to design new energy systems and plan for the longer term.

Technical, structural, and behavioural upheavals lie ahead. For example, on a technological level, energy production will likely be affected by rising river-water temperatures. Thermal power stations need cold water to operate efficiently. Their efficiency could therefore be reduced, calling their very existence into question! Hydro-electricity could also see its share decline due to predicted water shortages. Protection of marine fauna is also an issue. Discharging hot water from power stations into rivers that are already affected by warming would kill many species.

Renewable energies, whether biomass or other forms of renewable energy (wind, marine current or solar), could be impacted due to their vulnerability to extreme weather events. Beyond their intrinsic sustainability, the main challenge lies within political, economic and social decision-making.

As for household energy demand, we will see a significant shift from winter to summer: rising temperatures will cause domestic needs to shift from heating to air conditioning.

Finally, climate change could impact energy production itself, with changes to solar radiation due to more frequent cloud cover, changes in wind and rainfall patterns, reduced water levels and faster melting of the snow that feeds dams.

Renewable energy potential could be directly threatened. The challenge for scientific research is to redirect long-term energy concepts within just a few decades.
**ECO-DRIVING IS POSSIBLE!**

A SMARTPHONE DRIVING APP THAT CAN REDUCE FUEL CONSUMPTION BY 10 TO 15%

After having taken care of our health, our shopping and our fitness, our smartphones can now help us adopt green driving! The GECO app is an innovative, user-friendly Web 2.0 system than can reduce a driver's fuel consumption.

**WHAT IS ECO-DRIVING?**

While technical progress has led to more fuel-efficient cars, motorists can still influence their energy consumption. Maintaining a stable speed, anticipating traffic, changing gears to keep the revs low, maintaining the vehicle, avoiding unnecessary loads, driving more slowly and shutting off the engine when it is not needed are all eco-driving practices that save fuel. Eco-driving can also save drivers a lot of money and have a positive impact on road safety!

**Remarkable results**

Contrary to popular opinion, reducing speed is not only way to reduce fuel consumption and carbon emissions. GECO proves this because it acts on several driving parameters, without obliging the motorist to slow down. The app analyzes overall data for the journey and gives driving advice. It uses a detailed assessment of various journeys made by drivers to analyze their behaviour in more detail, develop points for improvement and monitor progress.

**User-friendliness**

Like every self-respecting app, GECO offers a user-friendly interface. Results are delivered instantly as graphics to be read at a glance!

**What is GECO?**

PRINCIPLE: GECO guides drivers to improve their urban driving behaviour.

After recording the characteristics of the vehicle and the number of passengers, this new driving companion uses existing smartphone functions, such as GPS, to calculate in real time the ideal driving behaviour to adopt, based on the journey. It then compares this to the drivers actual behaviour, and displays their score and the improvements to be adopted, along with practical advice. Energy performance is displayed, as is journey history, assessments and points for improvement.

**Coming soon: new energy efficiency, safety and maintenance services for the connected car.**

“Coming soon: new energy efficiency, safety and maintenance services for the connected car.”

**Destination: the connected car**

This new eco-driving system is a testament to the successful integration of information and communication technologies into cars: “The connection of vehicles to their environment (infrastructure and other vehicles) will make other functions possible. Eco-driving as currently implemented in GECO is only a first step to smarter connected cars.” explain the engineers involved in the app.

Available in the iPhone App Store and Google Play, the GECO app is free. Studies are already underway to offer new software services for connected vehicles, for energy efficiency, safety, prevention and maintenance, etc.

For more information GECO can be downloaded for free via www.geco-drive.fr

**© IFP ENERGIES NOUVELLES**

IFP Energies Nouvelles (IFPEN) is an international research institute in the fields of energy, the environment, mobility and materials. IFPEN brings together researchers from a wide range of disciplines, making it easier for them to share their knowledge and expertise and make an impact in the fields of energy, the environment and the movement and materials. The company is the French leader in the energy transition and has developed unique expertise in renewable energy, energy efficiency, safety and prevention, and the movement and materials. IFPEN is also a world leader in the production and use of alternative energy sources, and the company is committed to reducing its own energy consumption. **IFP ENERGIES NOUVELLES**
Organic waste is an innovative, green and widely available bio-resource, and a major asset for future energy. The Biorare project, led by French scientists and funded by the government’s Investing in the Future programme, uses biomass in the place of petroleum products. This reuse system is a serious option for the future of the planet.

Use of this bio-resource is a major step forward on many levels. Firstly, it allows significant savings in fossil resources, reserves of which are depleting every day. Secondly, the raw material, which is organic waste (household, food, green and agricultural waste), is inexpensive and widely available, because we all produce it in large quantities. Finally, this resource is renewable and will ultimately replace petroleum products, which are subject to international markets and harmful for the environment.

Biorare won the 2011 call for ‘Biotechnology and bio-resources’ projects of the French Investing in the Future programme. Launched using a ‘National Loan’, it is based on a technological breakthrough: microbial electrosynthesis, which is the production of organic compounds by the reduction of carbon dioxide, performed by microorganisms fixed to the cathode of an electrochemical cell. This process uses a biotechnological system (BES).

Use of this technique for processing organic waste has the advantage of combining waste treatment by oxidation with the production of useful molecules. This can be physically separated from the synthesis of chemicals of biological origin. It is therefore easier to recover the biomolecules and there is a lower risk of contamination.

Thanks to the National Loan and collaboration with major industry players, who are convinced by the possibilities of the project, technical, environmental, economic and acceptability specifications can be drawn up, with a view to preparing for future industrial roll-out.

The VASCO project dedicated to methanation on farms is studying ways to reuse CO2 emitted by industrial activity in the Fos-sur-Mer basin, in order to reduce greenhouse gases emissions into the atmosphere by means of purified CO2 in industry, acid gas injection into oil fields to optimize their yields, or geological disposal in the saline aquifers of the PACA region. Following initial research (2011-2012), a new promising avenue opened up: CO2 absorption via microalgae photosynthesis. This is the subject of the VASCO project (2015-2018), which will implement a marine algae production system over several hectares in the Mediterranean. The food or transport energy markets could be targeted.
Future habitats are being designed today. Our cities and administrations must face up to a number of challenges raised by climate change constraints. Energy, transport, urban planning and health are particularly concerned.

For urban areas, the challenge of climate change consists in providing solutions that target different scales at the same time, along with multi-scale solutions. For example, urban heatwaves, especially within ‘heat islands’, are a public health issue. Instead of air conditioning, less dense layouts could be considered, such as the greening of cities, which in turn places new constraints on sanitation and transport systems. In rural areas, the issues require even more complex optimisations, combining the long-distance transport of people and goods, and coordination with urban systems at various scales. Other problems associated with climate change are specific to coastal areas (rising sea levels), flood-risk areas (recurrent flash floods) and mountain areas (vulnerable areas), etc. All these regions have significant human activity.

The solutions sought must therefore address the overall issue by using multi-disciplinary approaches that bring together sociologists, economists, urban planners, and specialists in engineering sciences.
URBAN AND COUNTRY PLANNING

ALLENVI - COP 21 60 RESEARCH SUCCESS STORIES FOR A SUSTAINABLE PLANET

Sprawling or compact? Greener? Solar powered? Tomorrow's cities will shift to new architecture, and the behaviour of their inhabitants must change.

Sprawling cities

An urban heat island (UHI) is an urban area that is significantly warmer than its surrounding rural areas. While this is little affected by urban expansion strategies, the study noted that inhabitants would have reduced thermal comfort in a compact city, due to the concentration of people in the centre of the urban area. Furthermore, researchers found that the energy consumption of built-up areas is similar for sprawling and compact cities. Ultimately, management of urban sprawl has little effect on greenhouse gases emissions (resulting from building energy consumption), which are much more affected by the technologies used for transport.

Each inhabitant has a role to play

Good habits that residents can adopt include closing shutters during the day in the summer, using air conditioning sparingly, or turning down the heating (aiming for 19°C). The MUSCADE study concluded that the impact of our individual choices is comparable to the effects produced by technical solutions such as insulating buildings or planting green spaces.

The overall energy consumption of a city is strongly affected by its inhabitants’ behaviour.

MODELLING NEW CITIES

NEDUM, GENIUS and Town Energy Balance are three of the computer models used to simulate the city system. How it changes over time and processes associated with energy. NEDUM is an urban expansion model based on socio-economic mechanisms from 2000 to the end of the 21st century. Several forecasting scenarios have been studied. The GENerator of Interactive Urban blockS (GENIUS) method concerns the integration of building-scale data into urban microclimate and energy consumption modelling. It can assess the morphology of different scales. The urban microclimate is modelled using Town Energy Balance, which uses physical processes associated with urban layouts. A city’s energy consumption is represented by calculating the internal energy balance of buildings.

Sprawling or compact? Greener? Solar powered? Tomorrow’s cities will shift to new architecture, and the behaviour of their inhabitants must change.

M ANY RESEARCHERS ARE WORKING ON ESSENTIAL STRATEGIES FOR ADAPTING CITIES TO CLIMATE CHANGE. FRANCE IS AT THE CUTTING EDGE IN THIS FIELD, IN PARTICULAR WITH THE MUSCADE PROJECT (URBAN MODELLING AND ADAPTATION STRATEGIES TO ANTICIPATE ENERGY DEMAND AND PRODUCTION), WHICH BRINGS TOGETHER SEVERAL RESEARCH TEAMS FROM VARIOUS DISCIPLINES, INCLUDING METEOROLOGISTS, BUILDING ENVIRONMENT SPECIALISTS, ECONOMISTS, ARCHITECTS AND GEOGRAPHERS. AT ITS HEART IS THE INTERACTION BETWEEN CLIMATE CHANGE, ENERGY IN CITIES AND GROWTH AND DEMOGRAPHIC CHANGES. ALONG WITH ASSUMPTIONS REGARDING CHANGES IN URBAN AREAS (SPRAWLING OR COMPACT CITIES), CONSTRUCTION AND DECENTRALIZED ENERGY PRODUCTION TECHNIQUES (GREENING, SOLAR PANELS). THE INITIAL RESULTS WERE MADE PUBLIC IN OCTOBER 2014 IN PARIS, DURING THE CHALEUR SUR LA VILLE (URBAN HEATING) CONFERENCE.

WHAT

Better urban living

Sprawling or compact? Greener? Solar powered? Tomorrow’s cities will shift to new architecture, and the behaviour of their inhabitants must change.

The current decision-support tool aimed to provide decision support for the construction, maintenance and operation of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure.

ECORCE 2.0 decision-support tool extended.

For many years, civil engineers have expressed the need for assessment tools (methods, baselines, software) for sustainable development. The aim was to provide decision support for the construction, maintenance and operation of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure. The current decision-support tool (ECORCE 2.0) is a decision-support tool designed for decision making in the field of road infrastructure.
**MITIGATION**

**REDUCING EMISSIONS**

Mitigation aims to stabilize the concentrations of greenhouse gases in the atmosphere, either by ‘trapping’ the CO₂ already emitted, or by directly reducing emissions.

The overall aim of mitigation is to limit our direct impact on the climate system while protecting the environment. Limiting the concentration of greenhouse gases in the atmosphere is a major issue. Two complementary approaches are possible. The first is to reduce greenhouse gases production in the highest producing sectors such as energy, transport, construction, and industry, and the second includes the recovery, processing and sequestration of greenhouse gases. Reducing CO₂ emissions into the atmosphere involves a very large number of scientific programmes, including the development of new and renewable energies (such as photovoltaics, wind, and geothermal), the improvement of energy efficiency (of buildings, cars, etc.), and energy optimization for processes (in industry, transport, etc.).

The second component of mitigation, the underground sequestration of CO₂, has been developing for 30 years and is a promising avenue, although there is still the need to develop pilot schemes for the various geological and industrial configurations, and to convince society of its acceptability. For greater impact, it could even be possible to combine mitigation with the development of renewable energies, such as geothermal or biomass.

**CO₂ CAPTURE AND SEQUESTRATION**

Underground CO₂ sequestration is one of the solutions for reducing greenhouse gases emissions into the atmosphere. However, its consequences must be understood and its viability tested.

Although capturing CO₂ and reinjecting it into geological cavities is interesting from an economic perspective, French scientists explain that “the viability of the solution requires detailed understanding of the short- and long-term consequences of CO₂ injection into geological formations”. Deep geological formations provide natural “reservoirs” for disposal and confinement, over several hundred years, including empty oil and gas wells, deep saline aquifers and coal seams.

Research has focused on characterizing reservoirs, the consequences of CO₂ injection and the development of systems to prevent any risk of gas leakage from the reservoir, which could pose a risk to people, ecosystems and groundwater. Scientists are also studying how “injectability” (the ability to inject CO₂) would change over time, “as any reduction could limit the economic and technical durability of the operation”. This could be caused by various phenomena such as micro-cracking in porous environments, deterioration of the sealant used over time, acid attacks after CO₂ injection, or natural or artificial geological discontinuities.

**CO₂ sequestration in cultivated soil**

Agriculture produces about 23% of greenhouse gases emissions. With the help of French researchers, the Food and Agriculture Organization (FAO) has developed a method of adopting cropping techniques that promote carbon sequestration. They quantified greenhouse gases emissions and storage in the cultivated soils of tropical regions and developed the Ex Ante Appraisal Carbon-Balance Tool (EX-ACT) for calculations and to help decision-making. It assesses environmental projects, systems or policies by estimating the impacts of soil use and changes in use.

A food supplement for ruminants!

The level of atmospheric CH₄ (methane) has more than doubled over the last two centuries, mainly due to human activities, in particular raising cattle. Methane is a greenhouse gases 25 times stronger than CO₂. Use of a feed supplement from the fermentation of a cereal by a fungus of the Monascus genus, reduces ruminant methane production by 30%.

Although capturing CO₂ and reinjecting it into geological cavities is interesting from an economic perspective, French scientists explain that “the viability of the solution requires detailed understanding of the short- and long-term consequences of CO₂ injection into geological formations”. Deep geological formations provide natural “reservoirs” for disposal and confinement, over several hundred years, including empty oil and gas wells, deep saline aquifers and coal seams.

Researchers have developed a micro-algae production process combined with that of biogas, known as the AlgaPro. This new-generation process for bioenergy production can strongly rival that of other biofuels.

**Deadly micro-organisms**

Nitrous oxide (N₂O) is a powerful greenhouse gas that is also responsible for destroying the ozone layer. The ability of soils to eliminate N₂O is well known. Researchers have demonstrated that this can be explained by the diversity and abundance of a new group of microorganisms, capable of reducing it to nitrogen gas (N₂). These results underline the importance of microbial diversity in soil functions and the services it provides.

**CO₂ capture pilot project**

The European CASTOR project has launched a world-first pilot project for CO₂ capture at the Dong Energy coal-fired power plant in Esbjerg in Denmark. It demonstrated the ability to capture 90% of the CO₂ emitted by a coal-fired power plant through the use of suitable solvents.

However, there is still the problem of the legal and financial frameworks, which are not yet in place, and society is still reluctant regarding the idea of developing CO₂ sequestration. Potential deployment of this technology depends on political decisions.

**SOFTWARE FOR SAFER SEQUESTRAITION**

Researchers are developing software and technology to safely sequestrate CO₂. Their work involves site characterization, estimating sequestration capacities, risk analysis, optimizing CO₂ injection and geochemical monitoring using seismic signals.
Focus

How Can We Adapt to the Consequences of the Irreversible Rise in Sea Level?

New tools are available to identify the most vulnerable coastal zones in France. They are used to anticipate impacts and implement adaptation measures.

Since 2011, the rising sea level has been taken into account in coastal risk regulations. A 60cm rise in sea level must now be taken into account in coastal zone development programmes. This regulatory change is a significant example of an early adaptation measure that specifically focuses on one inevitable consequence of climate change. For this measure, research is required to provide tools to answer the following questions: what are the most vulnerable areas? Should we expect significant intensification of coastal risks from 2040, 2070 or 2100? Can the anticipated changes be modeled? How can changes to the frequency and intensity of marine flooding be assessed? French researchers have developed new tools to better assess the consequences of rising water levels and help the relevant stakeholders to adapt.

Diagnostic tools to identify the vulnerability of coastal sites

Work performed under various research projects on the topic of identifying critical sites and time periods related to the impacts of rising sea level has already helped to better identify how climate change can have varied effects on different coastal sites. Researchers have introduced diagnostic tools to assess the vulnerability of coastal zones at various time scales (2050, 2100, etc.). These forecasting systems take into account rising sea levels, its regional variations, the local geomorphological and geological context, land use and human activities. These approaches have been applied in Aquitaine and Languedoc-Roussillon and on Réunion Island, areas which, in some cases, have already been severely affected by coastal erosion and sea flooding.

At a Glance

The Loire estuary: what does the future hold?

Estuaries are fragile areas subject to reduced flows, increased risk of flooding, salt water ingress and silt movement. How will their saline and turbid content and morphology change? Tests using hydro-geomorphological modelling for different estuary types attempted to answer this question by studying estuary changes according to various climate scenarios. This study is now the basis for testing alternative methods for managing marshland used for extensive grazing or hunting activities (special case study in the Loire Estuary).

Land rezoning

How will the areas threatened by coastal risks be rezoned? It is important to have information on current and future marine flooding phenomena. The town of Hyères-les-Palmiers is carrying out a research project whose developments could be applied elsewhere. It involves exploring rezoning options for coastal areas (communities, transport, activities) on the basis of flooding risk predictions using high-resolution dynamic models (1m). This study illustrates the advanced capability of current modelling tools and the relative influence of hydrodynamic factors for 2030 and 2100.

Modeling storms to within 10 cm

Which coastal zones would potentially be flooded during storms if the sea level rose by 20 to 60cm? This is very complex to assess due to the extensive spatial variability of extreme water levels during storms. However, a recent research programme helped improve current hydrodynamic models to reach a level of accuracy to within less than 10cm. These unrivalled levels of precision help better model the effects of storms.

Coastlines are where air and land meet the sea and are sensitive to climate change. What risks do they face? What solutions does research offer?

Coastlines are fragile areas subject to rising temperatures and the acidification of marine water. Within a few centuries, the melting of the polar ice caps could increase the sea level by several metres, affecting 10% of the world population and increasing the number of climate refugees. Researchers have the three-fold objective of better understanding these fragile environments, characterizing the phenomena associated with global climate change and proposing sustainable management methods.
ANTICIPATING THE RISKS ASSOCIATED WITH CLIMATE CHANGE

Coastal flooding, heavy rain and extreme floods, sinkholes and landslides are just some of the many natural risks that accompany climate change and its major consequence, rising temperatures. Risks are the combination of potential hazards and vulnerabilities, and are key international issues.

Hazards, such as earthquakes, flooding, storms, and forest fires, are not just random events. As research and technology progress, experts are now able to identify causes, analyze and quantify these phenomena, and even predict them, at least in the short term. Vulnerability, which is related to land development, is also the subject of study for researchers aiming to reduce it. For example, this could mean preventive measures (such as adaptation of urban areas, or enhanced technical specifications for constructions), supplemented by crisis management, public protection and warning systems and the deployment of special measures.

Risks are studied by scientists as an overall entity. They affect whole spheres of political, social and economic life. In particular, the issue is to change the behavior of communities in the face of risks, which raises the question of property rights, for example when confronted with rapid coastal erosion or with regard to construction permits for areas at risk of flooding.
What preventing glacial risks?

Over 99% of the Earth’s fresh water exists in ice formations or underground. French geophysicists have developed an innovative method based on nuclear magnetic resonance (NMR). It is used for preventing the risks associated with the accumulation of meltwater under glaciers due to global warming.

Measuring the magnetic field of water in rocks

“Currently, this is the only surface-based technique capable of detecting liquid water below ground or under a glacier and estimating its volume,” say researchers.

In contrast to soundings or boreholes, NMR is a non-invasive method. The water studied is located at approximate depths of 0 to 100 metres. An alternating current generated by researchers at the ground surface creates an electromagnetic field which in turn triggers the resonance of the water molecules held in the rock underground. This magnetic field is then measured.

A technique for prevention of deep-water risks in semi-arid and mountainous regions.

The NMR method is used only for detecting quantities of underground water, unlike traditional geophysical techniques that analyze anomalies in structures or physical parameters. NMR has demonstrated its effectiveness in quantifying hidden water resources in many tropical regions. It has also found an unexpected application in mountains, where water can become trapped under glaciers, forming a subglacial pocket. If the glacier wall fails, this can directly threaten inhabited areas below.

The only solution is to drain the water pocket before its sudden release. The NMR method has thus proved to be applicable in many regions across the world.

Anticipating natural risks in mountainous areas

The RHYTMME project (from the French acronym for hydro-meteorological risks in Mediterranean mountainous areas), combines a network of next-generation radars and a web platform for mapping hydro-meteorological risks. Along with the cumulative rainfall maps provided by the radars, users have real-time access to the maps produced by a flooding risk warning system. Other mountain risks can be viewed on the platform such as the risk of debris flows, landslides and rockfalls. The aim is to predict hazardous phenomena in mountainous areas, whose frequency could increase with climate change.

Rainfall monitoring: mobile phones are taking over

Rainfall monitoring is vital in many research fields (hydrological, climate and agricultural modelling), and operations (such as meteorology, water supply services, food security, and flood and drought warnings). However, observation networks remain insufficient. This is not the case for mobile phone networks, which provide coverage over 70% of the planet’s landmass and 90% of the world’s inhabited areas. Besides transmitting radio signals, they record signal disturbances, which are partly due to precipitation, to ensure the quality of networks. The idea of the researchers is to benefit from this data to improve rainfall monitoring and spatialization. The method has just proved its effectiveness in Burkina Faso, where it was found to be 95% reliable in detecting rainfall events.

Air quality: possible scenarios

Using large-scale multi-model comparison, a comprehensive study on air quality has estimated changes in atmospheric composition due to climate change, for both gases and aerosols, over the 1850-2100 period. Ozone has increased sharply since 1850. According to the various scenarios studied, changes by 2030 and 2100 show different trends: an optimistic scenario predicts a reduction by 2030, while in others the reduction occurs between 2030 and 2100, except for one scenario in which tropospheric ozone concentration continues to rise steeply.

Permafrost risks

Typical of arctic regions, permafrost is soil that has been frozen for thousands of years, representing 25% of the Northern hemisphere landmass. It is gradually defrosting due to global warming, in turn releasing powerful greenhouse gases, mainly CO₂ and methane. This phenomenon has been widely underestimated in climate models.

More frequent forest fires

A group of researchers aims to characterize changes to the risk of forest fires in France based on the Forest-fire Weather Index (FWI). Global warming is expected to increase this risk. A comparative study of the 1961-1980 and 1989-2008 periods shows a marked increase in mean FWI over the whole country, with a 22% increase over the year and a 24% increase in summer. There is also a very marked local increase: the index can reach 20 in some southern areas such as Herault and Southern Corsica. It is feared that this may mean a longer wildfire season and an increase in the number of regions affected by forest fires.
The 12 founder members

- The French Geological Survey (BRGM)
  - As the national geological survey, the BRGM is the key public body in the field of earth sciences, for managing soil and subsurface resources and risks.
  - www.brgm.fr

- The French agricultural research and international cooperation organization (CIRAD)
  - CIRAD produces and shares new knowledge to support agricultural development and contributes to the debate on major issues in global agriculture.
  - www.cirad.fr

- The French Centre for Scientific Research (CNRS)
  - The CNRS operates in all fields of knowledge, with over 1,200 laboratories. It is the primary partner of higher education and research institutions in France, and a major player in research at the European and international levels.
  - www.cnrs.fr

- French Research Institute for Exploitation of the Sea (IFREMER)
  - IFREMER contributes to the knowledge of oceans and their resources, to monitoring marine and coastal environments and to sustainable development of maritime activities. To achieve this, it designs and develops observation, experimentation and monitoring tools. Since 2008, IFREMER’s ships have been part of the TGIR (very large research infrastructure) oceanographic fleet.
  - www.ifremer.fr

- French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR)
  - IFSTTAR performs mission-oriented research work and consulting in the areas of transport, infrastructure, natural risks and urban planning, to improve the living conditions of our fellow citizens, and more generally, to promote the sustainable development of our societies.
  - www.ifsttar.fr

- National Institute of Agricultural Research (INRA)
  - As the leading agricultural research institute in Europe, INRA produces scientific knowledge in three fields: food, agriculture and the environment, with the aim of helping to sustainably feed the world.
  - www.inra.fr

- National Institute of Demographic Studies (INED)
  - INED is a research organization of international standing in the field of demographic studies.
  - www.ined.fr

- French Institute for Radiological Protection and Nuclear Safety (IRSN)
  - IRSN is a national administrative institution that performs research aimed at improving the health safety of the population, and the protection of individuals and the environment against the effects of ionizing radiations.
  - www.irsn.fr

- National Institute of Geographical Information andCartography (IGN)
  - IGN is a public service that provides products and services to territorial stakeholders, in particular for public authorities, to support their decision making and produce maps.
  - www.ign.fr

- National Institute for Radiological Protection and Nuclear Safety (IRSN)
  - IRSN is a national administrative institution that performs research aimed at improving the health safety of the population, and the protection of individuals and the environment against the effects of ionizing radiations.
  - www.irsn.fr

- French Atomic Energy Commission (CEA)
  - The CEA operates in four major fields: atomic energy, IT and healthcare, low-carbon energies, and environmental and occupational health and safety.
  - www.cea.fr

- National Agency for Food, Environmental and Occupational Health & Safety (ANSES)
  - ANSES is a public service that issues and applies regulations to protect public health, especially in food and the environment.
  - www.anses.fr

- French National Centre for Space Studies (CNES)
  - CNES is the French space agency, founded in 1963.
  - www.cnrs.fr

The 16 associate members

- The French Agricultural, Veterinary and Forestry Institute (Agreenium)
  - www.agreenium.org

- Conference of the Directors of French Engineering Schools (CDEFI)
  - www.cdefi.fr

- Conference of Grandes Ecoles (CGE)
  - www.cge.asso.fr

- Centre for Studies and expertise on Risks, Environment, Mobility, and Urban and Country Planning (CEREMA)
  - www.cerema.fr

- French Polar Institute Paul Emile Victor (IPPCV)
  - www.ippcv.fr

- French Research Institute for Industrial Safety and Environmental Protection (IFSTTAR)
  - IFSTTAR performs mission-oriented research work and consulting in the areas of transport, infrastructure, natural risks and urban planning, to improve the living conditions of our fellow citizens, and more generally, to promote the sustainable development of our societies.
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  - www.irsn.fr

- National Centre for Computer Science and Applied Mathematics (LIRMM)
  - www.lirmm.fr

- National Laboratory of Cartography and Geodesy of the French Navy (SHOM)
  - www.shom.fr

- National Laboratory of Hydrography and Oceanography (LNO)
  - www.lno.fr
AllEnvi was created on 9 February 2010 at the initiative of 12 founder members, and is one of five thematic research alliances.

The 12 founder members

12 FOUNDER MEMBERS

16 ASSOCIATE MEMBERS

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