L – IPSL LABEX

MID AND LONG-TERM ACTION PLAN

JUNE 2013

This document describes the mid and long-term strategy and objectives of the LABEX program, summarizes the current starter actions, the methodology, and describes research, innovation and expertise transfer and education propositions for the mid-term. It is an update of the 2012 action plan.

This document follows the same structure as the 2012 Action Plan. It contains however a number of new elements and modifications, summarized below:

Research:

- **The document now includes long-term directions (Section 2.2) as suggested by the scientific committee**
- **The initial program of actions is now closed (2011-2013). For each selected action, a summary of what was done is now included in Appendix A**
- **Projects in the mid-term program took longer than expected to start, mainly due to our wish to have well-defined post-doc profiles and candidate selection process. Most post-docs are now either just hired or will be hired before the end of 2013. These profiles are included as Appendix B. An update of proposed action can be found in the WP description Section 2.3, in particular when a project was funded and started**
- **Previous section 2.4 was removed as it was mainly necessary in the initial construction stage.**
- **The research budget is updated (new Section 2.4) and contains new funded actions**
- **New projects with LABEX MER are proposed, as suggested by the scientific committee**

Innovation and transfer:

An update of innovation and transfer plans is provided. It contains in particular a more accurate of climate service actions and the first version of the strategic plan for climate services at L-IPSL in Appendix C.

Education:

An update of innovation and transfer plans is provided

Contents

1. Elements of context, objectives

1.1 Elements of context

The L-IPSL LABEX is a climate change program hosted by the IPSL federation. The IPSL federation gathers 6 laboratories in the Paris area (LATMOS, LISA, LMD, LOCEAN, LSCE, LPMAA). The L-IPSL project is carried out in partnership with two other laboratories (IDES and SISYPHE).

The project, as it was approved by the "Investissements d'avenir", has 3 interlinked dimensions:

(a) A project to accelerate research in a few directions which are key to improve our assessment of future climate change (but reversely do not encompass the totality of the IPSL research).
(b) A project to enhance educational actions on climate change.
(c) A project to favor transfer innovative activities from the IPSL to external partners, including emerging companies.

Although their aims differ, there is of course a necessity to maintain a strong consistency between those actions. This document describes mostly the projected research agenda of the LABEX. The interactions between this research agenda and the educational and innovation activities are also underlined.

The program started in September 2011. The initial proposal described a general long-term vision of the LABEX but no implementation plan. Along the first few months a methodology to design that plan was discussed. The agenda of the LABEX was then structured into 3 phases as illustrated below (see Figure 1 below):

- **an initial phase (2011 – mid 2012) where three programs were proposed in order to (i) invite foreign scientists to start working on key issues (ii) initiate or develop collaborations between IPSL and the two new laboratories , and (iii) strengthen IPSL infrastructures (modeling and data bases) which are required for the future LABEX work,**
- **a mid-term phase (mid 2012 – mid 2014) where research projects will be developed,**
- **a long-term phase (mid 2014 – 2021) where the initial vision will be further developed.**

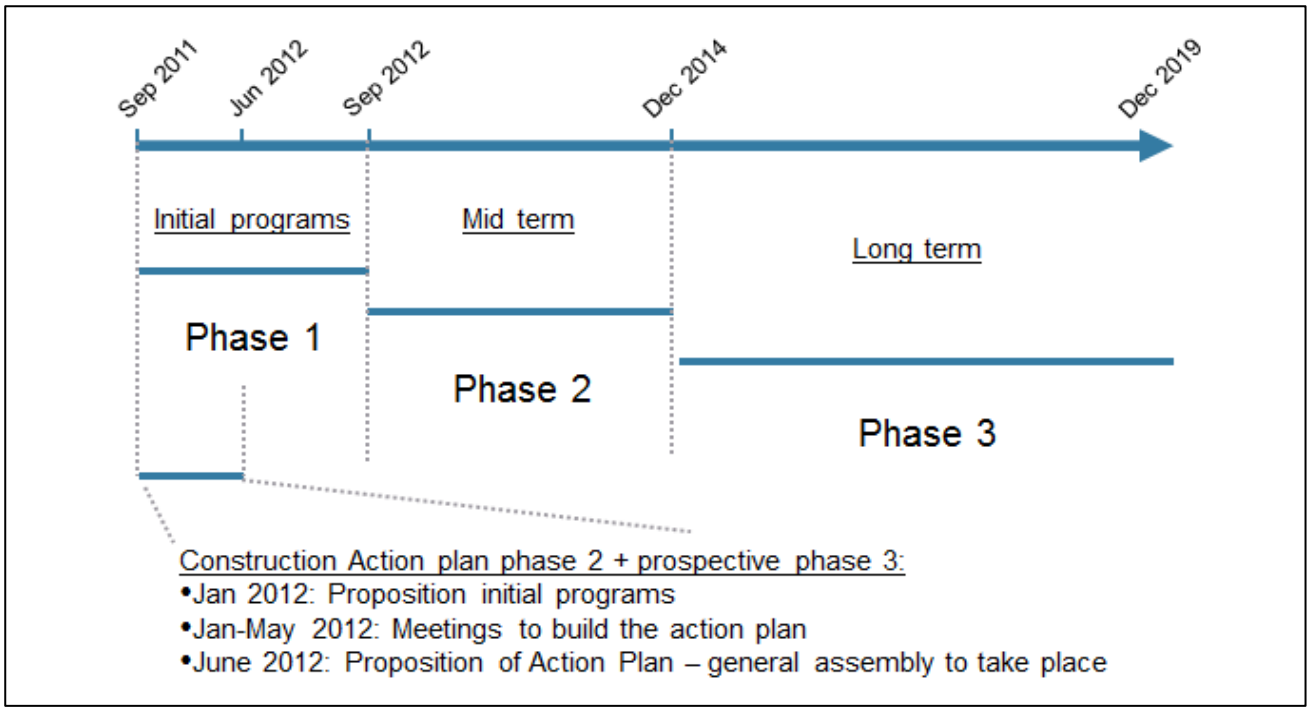


Figure 1: Phases of the LABEX program

1.2 Objectives of this document

The initial phase is now finished and the mid-term phase has started. This document is therefore an update of the 2012 action plan. It contains a report for the initial phase actions and a consolidated view of the mid-term plan, including new projects starting by the end of 2013.

The objectives are therefore:

- **to recall the main long-term issues, objectives of the LABEX program,**
- **to summarize the actions decided in the initial phase and to report them**
- **to summarize the complete research work that is intended in the mid-term perspective to fulfill the LABEX main objectives,**
- **to identify specific and burning issues where a focused LABEX effort will be developed during the mid-term phase and propose concrete research work,**
- **to propose longer-term issues that should be addressed by the LABEX program,**
- **to propose targeted training, innovation and transfer of expertise actions.**

1.3 General objectives of the LABEX as described in the proposal

Mitigation of and adaptation to climate change are among the largest collective challenges that our societies need to face during the next decades and beyond. The last IPCC report stated that global warming

is unequivocal and will amplify in the coming decades due to the increase in atmospheric concentrations of long-lived greenhouse gases. The design of adaptation policies and strategies for energy use and production, as well as the management of limited environmental and energy resources require all a rapid increase in our understanding of the climate system and our capacity to predict its evolution with the largest possible accuracy on relevant space and time scales. The LABEX program is designed to provide improved climate understanding and tools, as well as education actions and a strategy for transfer of expertise and innovation based on the skill and tools of the laboratories partners of the LABEX.

For the research program, the LABEX project aims at addressing the following key (broad) questions

(1) How far can we robustly anticipate the future evolution of the atmospheric composition, which depends on a very large number of factors including socio-economic drivers?

(2) How can we determine what is actually predictable in terms of future climate evolution, in a system that combines anthropogenically and other externally induced changes and natural fluctuations?

(3) What are the relations between the global evolution of the climate and its regional consequences?

(4) How much do these local or regional climate evolutions impact environmental resources such as freshwater availability, air quality, and oceanic and terrestrial ecosystem services including the maintenance of biodiversity?

(5) How can we assess the potential impact of unpredictable “climate surprises” that may result from the rapid non-linear behaviour of Earth System components?

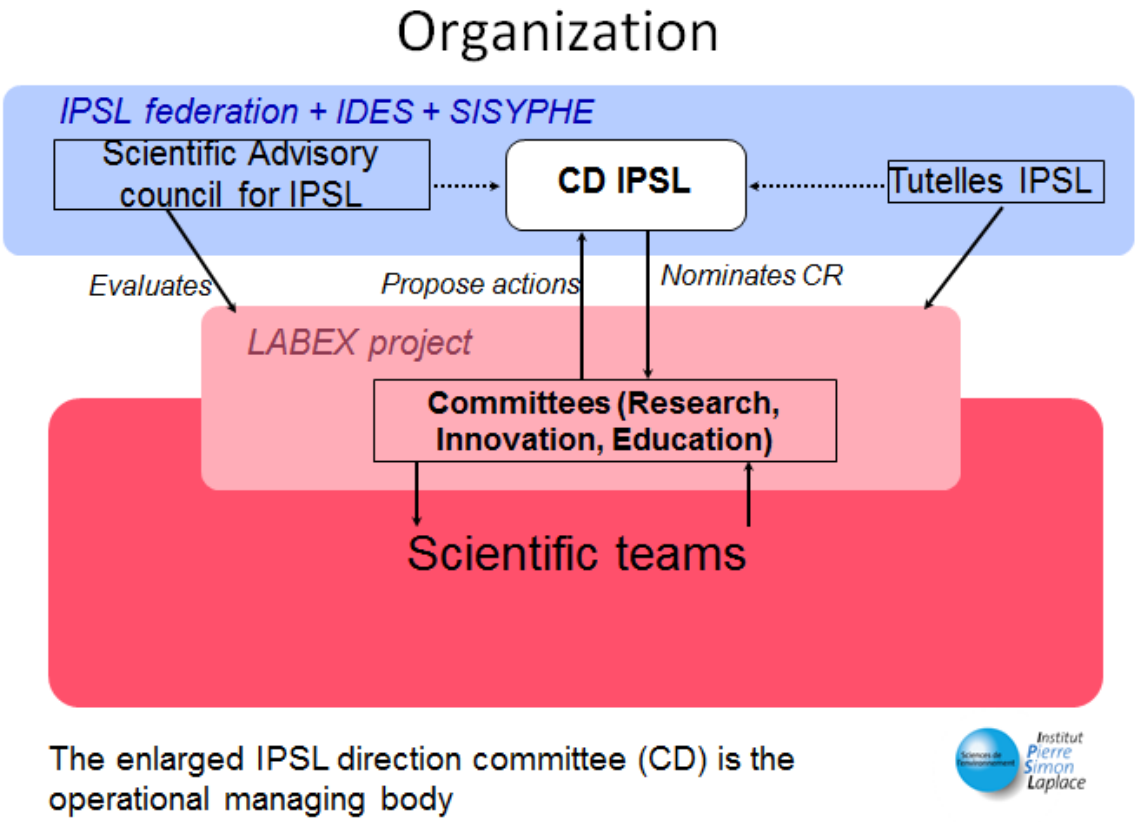
Research is structures in thematic and methodological work packages that address these questions, and rely on existing IPSL infrastructures (modeling, observing strategies) and will benefit from methodological developments for uncertainty estimation.

The LABEX will also develop an important innovation and expertise transfer program, especially in the domains of innovative instrumentation, modeling and toward the development of climate services.

The LABEX will also bridge training and education with the rapidly developing climate science.

1.4 Governance, in a nutshell

The LABEX program is steered by an institutional steering committee (the “tutelles”), advised by an advisory committee which evaluates the program and the strategy. The Direction Committee (CD IPSL) gathers the direction of IPSL, and the managing directors of the partner laboratories. It nominates the members of the internal committees (research, innovation and education), proposing the action plans and are responsible of the LABEX evolution operational management.



Schematic picture of the LABEX organization

1.5 Steps

For research, during fall 2011 several discussions took place on to how to conduct the LABEX research projects and where effort should be put for a higher efficiency. From the analysis of the ambitions, as compared to limited funding and the size of the research community involved (about 1000 staff), the first conclusion was that the program would benefit from a large-scale participation of staff within concerned laboratories, in order to exploit the strength of already organized expertise and to initiate collaborative actions where the community is less structured, seeking to fund seeding projects.

The steps followed by the LABEX Research Committee to construct a mid and long term action plan, which includes the WP leaders, were then:

- **a series of IPSL meetings for general information and discussion about the LABEX program**
- **a 2-day synthesis committee seminar (19/20 march 2012) to design the mid-term action plan**
- **the writing of the initial (2012) mid/long term action plan, in June 2012**
- **a series of monthly or bi-monthly meetings during fall/winter 2012-2013 in order to follow initiated actions and to discuss new ideas**

- **the writing of the updated action plan (2013)**

The method used is the progressive construction of the program by the research committee, interacting with the LABEX teams, and not a series of project calls.

For education and innovation: an education committee and two innovation committees (instrumentation and climate services) have been set up and defined a strategy and proposed the first LABEX actions.

1.6 Long-term aims of the L-IPSL

The LABEX project has an important specificity compared to classical projects: it runs over 10 years, which enables to define long-term goals. After the first phase, a number of goals have been identified, which must be progressively updated and specified along the first years. In summary these goals are:

- to strengthen and further develop the research community in the Ile-de-France working on climate change **area by developing coordinated actions and further sharing and mutualizing research tools and data; this will be achieved by fostering coordinated actions on observation and simulation data bases and portals and ways for a better synergetic use of such data; this will also be achieved by developing large-scale research projects using these data**

- to develop a modeling capacity to simulate and predict climate at a spatial scale and with processes allowing impact assessments and adaptation strategies: **this will be achieved by developing new model versions of the IPSL model adapted to the high-performance computing power (new grids such as finite volume on "cube spheres" or "icosahedral grids", new dynamical cores, new tools for i/o), as well as further developing integration of improved physical and biogeochemical processes (C, N and other cycles, aerosols, clouds and convection);**

- to develop an "indicator factory" downstream of model projections, to be used for impact studies and more generally for climate services: **A systematic methodology will be set up by examining impact needs (from existing and new projects), producing the indicators starting from global climate projections and downscaling these projections, evaluating these indicators and their uncertainties, and applying impact models in a few selected sectors where LABEX teams have projects using such models;**

- to ease the development of new instruments and observation strategies for climate monitoring of essential climate variables: **this includes for instance the development of new lidars measuring both the content of water vapor and aerosols in the atmosphere, or a coordinated strategy on stable water isotopes monitoring; other new observing strategies will also be designed;**

- **to further improve the model / observations integration by improving the capacity of comparing observations and simulations:** on the observation side, this will be achieved by formatting data bases and defining new products better adapted for model comparison, and by studying new

processes during field studies. New products in models and simulation data, for instance the development and integration of the stable water isotope evolution modules in all compartments will be included in the coupled model;

- to build education bridges between the continuously evolving research proposed by the labex**, the multi-actor higher-education system, and the increasing demand of knowledge from various sectors of the society about the climate issues.**

2. Research activities

2.1 Summary of actions proposed for the initial phase

In the initial phase, the LABEX research program focused on actions that could both be developed rapidly and satisfy the objectives of the LABEX. Three types of actions were proposed, on the basis of responses to an internal call. These actions are summarized below, and reports can be found in Appendix A:

- ***Invitation of foreign scientists to L-IPSL laboratories for a short period of time***

Host Laboratory	Name	Project	Affiliation	Duration (months)	Estimated budget (keuros)
LATMOS	Andrew Heymsfield	Ice cloud study	Mesoscale and Microscale Meteorology Division, NCAR	3	15
	Amato Evan	Coupling between aerosols, oceanic and atmospheric dynamics	Department of Environmental Sciences, University of Virginia	6	38
	Jerome Fast	Climate-Chemistry Interactions	Atmospheric Science and Global Change Division, Pacific Northwest National Laboratory	3	15
LSCE	Peter Raymond	Carbon transfer in rivers	Yale School of Forestry and Environmental Studies, Connecticut, USA	1,5	9
	Hema Achyuthan	Evolution of paleo-monsoons	Anna University, Chennai, Inde	3	15
IDES	Steve Clifford	Permafrost studies	Lunar and Planetary Institute, Houston, TX	2	10
LOCEAN	Alessandro Tagliabue	Impact of CC on marine ecosystems	CSIR/University of Cape Town, Cape Town, South Africa	3	10
					112

- ***Projects integrating IPSL laboratories with one of the new LABEX partners (IDES and SISYPHE)***

Laboratory	Support proposition	Estimated budget (keuros)
IDES-LSCE	Co-funding of shared analytic platform facility IDES-LSCE	35
IDES-LSCE	PERGELENA: Study of a Talik under climate change	5
SISYPHE	GRP-Ô: concept study of a radar for soil water measurement	10
SISYPHE-LMD	CHARM: Evaluation of the new ORCHIDEE version in climate change conditions	17
SISYPHE-LMD-LSCE	HYDRO-ORACLE: impacts of CC and LU change using ORCHIDEE	13
Total		**80**

- ***Infrastructure resources for the development of the LABEX (TWP1 & TWP2)***

TWP	**Proposition**	**Estimated budget (keuros)**
TWP1	Co-funding of data storage for CMIP5	10
	Funding of 6 month engineer for CMIP5 data base support	25
	Public access of articles describing the IPSL model	2
	Support to workshop CFMIP	3
TWP2	Construction of level-3 observation data base within ESPRI	40
Total		**80**

2.2 Long and mid-term research issues

Long term research aims

Climate change science has long-identified challenges, but the tremendous amount of syntheses and assessments made in the WGI 5th IPCC report brings new ones. Less uncertain projections of climate change crucially rely on more accurate estimations of the climate sensitivity to external forcings. However climate sensitivity results from the complex interplay of direct forcing effect, feedbacks and energy exchanges among all compartments of the earth system. Less uncertain projections also rely on an improved understanding and quantification of climate variability, especially at decadal to multi-decadal scales. Changes at these time scales, such as the recent slowdown in surface warming, hinder accurate estimation of climate sensitivity and attribution of long-term changes. The simulation of regional climate, with phenomena ranging from the meso-scale interacting with the circulation at global scale remains a challenge because of the wide spectrum of scales and processes to be accounted for. For instance the African monsoon region undergoes such poorly understood interactions. A better prediction of regional phenomena such as rainfall regimes is necessary to better estimate climate change impacts which remain highly uncertain in such vulnerable regions.

Given the expertise of LABEX research teams, the major long-term overarching research goals are threefold:

- Provide improved estimates of the climate sensitivity to natural and human driven forcings: **L-IPSL teams have leading expertise in earth system physics, biogeochemical cycles, their interactions and feedbacks. This expertise should allow to better quantify least documented interactions such as interactions between carbon cycle, aerosols, chemistry, the atmospheric circulation, and carbon exchange between several components where uncertainty is large (soil, rivers, …); The expertise in paleo-climate reconstruction and modeling should help quantifying robust feedbacks both in the current and past climates; L-IPSL teams also have sufficient expertise to better document the sensitivity of climate to solar and volcanic forcing, with climate experiments simulating the effects of major volcanic eruptions and solar forcing variations;**
- Provide an improved attribution of recent decadal to multi-decadal changes of the climate to forcings and natural variability: **the expertise in paleoclimate, as well as ocean-atmosphere coupled modeling, the emerging expertise in initialized climate simulations, as well as the online simulation of more interactions with biogeochemical cycles should help characterizing changes at the scale of a few decades, which is particularly relevant to adaptation; the expertise in statistical analysis of climate data should also help to develop detection and attribution studies in combination with modeling experiments. In particular, these combined studies should lead to understanding the mechanisms involved in the recent slowdown of surface temperatures;**
- Provide better and more reliable projections of climate and related impacts in a few key sectors at both global and regional scale: **the expertise in climate modeling and impacts of climate change is present or emerging in several L-IPSL teams. For instance, the impacts of climate on ecosystems, water resource, agriculture and energy is an expertise that has grown through several projects over the past decade. The large participation to CORDEX exercise has demonstrated the growing involvement of L-IPSL teams in regional climate modeling. This should enable major advances in the framework of the LABEX, as concerns the implications of climate change in several regions of**

the world, including the national level. At a more fundamental level, a deeper understanding of the interactions among regional processes and between regional and global circulations is necessary, and the best way to model these interactions should be identified. The development and a larger use of zoomed, coupled versions, with nudging possibilities, of the IPSL-CM model, used in combination with other regional models (WRF, MAR) should help this.

In the long-term, collaboration with the LABEX MER will be strengthened. Several topics have been identified for such collaborations, such as climate change studies involving the rise of the sea level and its impact on coasts, the role of small-scale physical processes in the ocean on marine biogeochemistry and on the biological carbon pump, and the impacts of climate change on marine ecosystems. Some aspects of this collaboration are developed in the contributions of WP1 (Factors controlling the atmospheric composition) and WP4 (Impacts).

The mid-term program developed below includes projects aimed at answering these main issues, and are gathered into 5 main issues:

Issue 1: The predictable part of decadal to multi-decadal climate changes and risk of abrupt changes

Efforts are being undertaken to identify predictable climate variations at decadal to multi-decadal scales through several projects: on the one hand, the effect of external forcing is being studied through the simulation of major volcanic eruptions occurring along the last millenium and their comparison with paleoclimate records, building upon a large spectrum of expertise within the LABEX teams. The predictable part of decadal variability is also being studied through the recent completion of initialized climate hindcast simulations (CMIP5) and associated idealised studies designed to understand the mechanisms involved. These activities, funded both by the Labex and by national and EU projects, are now coordinated at the IPSL level and contribute to the very active international agenda in the field of decadal predictability (WCRP, CLIVAR, GFCS, CMIP). Abrupt changes have also occurred in past climates, especially in the North Atlantic area. Understanding their mechanisms and links to decadal and multi-decadal variability requires improving significantly the synchronization of the various paleoclimatic records, an effort that is currently being undertaken using advanced mathematical methods. At the scale of the century, the predictable part of changes is the effect of greenhouse gases. The climate sensitivity to GHGs, incorporating a variety of feedbacks will be studied along the lines of the WCRP Grand Challenge on “clouds, circulations and climate sensitivity”, with a contribution of the LABEX on the study of cloud-circulation feedbacks, especially in tropical regions, and using both recent past, future, paleo or idealized simulations simulations (CMIP5, PMIP3, CFMIP).

Issue 2: Trends in marine and terrestrial ecosystem productivity and carbon fluxes

Targeted research efforts are being undertaken in order to better quantify and understand the carbon sinks, both in the ocean, over land, and their future evolution in response to 1) climate change, 2) atmospheric CO2 change, 3) land use change, 4) atmospheric aerosol changes and 5) human inputs of nutrients and contaminants. An essential step, expected in the next few years, will be to quantify and simulate the interactions between the carbon cycle, the aerosols, including the effects of aerosols on productivity through their radiative forcing, the “fertilizing” effect of aerosols deposited over terrestrial

ecosystems (nitrogen oxides and ammonium, phosphorus from dust) and over the ocean (nitrogen oxides and ammonium, iron and phosphorus from dust). To meet this objective, a review of processes will be achieved in order to improve the biogeochemical IPSL climate model components, by analyzing CMIP5 simulations with interactive biogeochemistry and climate, and carrying out complementary offline simulations to attribute changes in primary productivity over the 20th Century to the above drivers. In parallel, the linkage between land ecosystems and the oceans through the transport of carbon and nutrients from land to ocean by rivers and estuaries will be studied. This significant and over-looked loop of the global carbon, nitrogen and phosphorus cycles will be progressively included in the land model ORCHIDEE, and explored in the ocean biogeochemical model PISCES, bridging the gap between the expertise existing at SISYPHE, LMD, LSCE and LOCEAN. This effort will be linked to process studies in key regions in order to capture the sensitivity of transfer and transformation processes to climate and environmental changes. The Arctic is a region both where productivity is changing rapidly, as evidenced by 30 years of satellite vegetation index and a large number of ecosystem measurements, and where the transfer of organic matter by rivers to the Arctic Ocean is currently altering marine biogeochemistry and air-sea CO2 fluxes. Specific emphasis will be given to the attribution of Arctic productivity changes in this action. On the ocean side the LABEX team will benefit from a strengthened collaboration with the LABEX MER for some of these actions.

Issue 3: Changes in the precipitation regimes and water resources

Efforts are being undertaken to develop a capacity to better predict water resources under climate change. This requires several emphasis in the LABEX mid-term research : (i) to enhance understanding of the drivers (i.e. cloud-scale processes as well as environmental forcing) and improved modeling of rainfall regimes, which are currently not well predicted by climate models ; specific questions are (a) how to model precipitation regimes which depend on weather systems lying over a wide range of scales, and (b) how can high-resolution convection-permitting regional limited-area models be used to assess the quality of and improve precipitation fields in GCMs at intermediate scales (i.e. scales covered by both modeling approaches); (ii) to develop a capacity to predict future river discharges, droughts and floods due to extreme events. Downscaling model chains, either of statistical or dynamical nature, offer many possibilities and properties to be explored in combination with existing observations, especially regarding the water cycle phenomena. They raise methodological issues that need to be investigated. Major efforts will be to bridge across spatial scales, accounting for model biases, and to combine and evaluate the use of indicators specific to hydrology. The emphasis during the mid-term LABEX phase has been put on (i) the analyses of the many simulations made within the framework of CMIP5 and CORDEX over the African monsoon region, and on (ii) developing and analyzing indices of rainfall impacts over the same region. The expertise of L-IPSL on water isotopes will also be used to study the water cycle: a novel database on water isotopes covering current observations, paleoclimate archives and simulations will be built. This will help to (i) better constrain the mechanisms that control evaporation, precipitation and transfer processes in relationship to changes in water phase, (2) provide a robust framework for data/model comparison, and (3) better reconstruct changes in the water cycle evidenced by paleoclimate records.

Issue 4: Fast warming and atmosphere, ocean, cryosphere feedbacks with a focus on the Arctic region

Clear evidence for fast climate change is being observed at northern high latitudes in the form of diminishing summer sea-ice extent, thawing permafrost and changes in the Greenland ice sheet etc. Anthropogenic forcing, both local and remote, is clearly playing a role but complex interactions with natural physical and biogeochemical cycles in the atmosphere, ocean and cryosphere make changes in this region difficult to predict with current climate models. Feedbacks resulting from climate change impacts on the fragile polar ecosystems and biogeochemical fluxes at northern high latitudes also need to be better understood and represented in climate models which currently perform poorly in this region. Improvements in the capability of the IPSL model in the longer term can be achieved by a combination of improved process level understanding coupled with data analysis and high-resolution modeling leading to improved climate predictions and estimations of ecosystem feedbacks. Further exploitation of existing observations, with additional coordination at the level of L-IPSL, will contribute to this aim providing information with which to assess model performance. This will enhance the potential contribution of L-IPSL to the new national effort (the CHANTIER ARCTIQUE) on focusing on the Arctic.

Issue 5: The indicator factory

An effort to develop and evaluate communicable and useful climate indicators of climate change is to be developed. Indicators include classical climate indices, but a specific effort will be made to develop new indices of climate change detection such as the "time of emergence" in both climate variables and impact variables, and impact-oriented indicators. A methodology will be developed, starting from impact needs as seen in ongoing impact/adaptation projects, then developing and evaluating impact and climate indicators. The methodology will also include a review of the indicators developed in ongoing and forthcoming impact and adaptation studies.

2.3 Contribution of Work Packages to the LABEX objectives

The actions contributing to mid-term issues defined in this section have various degrees of maturity. Some mature actions are proposed for funding by the LABEX while others will be discussed again in workshops and in an updated version of this action plan during Spring 2013. Thus the action plan proposes funding only for the most mature propositions.

- ***Work Package 1: Factors controlling the atmospheric composition***

Main objectives and strategy

The future evolution of the Earth's radiative forcing will depend upon anthropogenic activities, reflecting economic development pathways and the structure of energy production systems, as well as the response of natural biogeochemical cycles.

Over the past two decades, 80% of the increased radiative forcing of long lived greenhouse gases is caused by the emissions of CO2 from fossil fuel burning and land use change. This illustrates how crucial is the **carbon cycle in controlling the future rate of climate change**. Roughly half of the current anthropogenic

CO2 emissions are absorbed by natural sinks in the ocean and in terrestrial ecosystems. But models of the coupled climate-carbon system consistently predict that future climate change will reduce the ability of natural sinks to continue to absorb anthropogenic CO2.

Like the carbon cycle, **other long lived greenhouse gases** with a global warming effect, CH4 and N2O, also have an anthropogenic and a natural component linked to land and ocean biogeochemistry and to atmospheric chemistry. The evolution of these two components in response to climate and atmospheric composition changes is important to quantify and understand, including the underlying processes.

Short-lived aerosols and reactive gases are produced by a variety of processes and transported away from emission regions. Unlike long lived greenhouse gases, these species exert a regional climate forcing, which can be either positive or negative in the case of aerosols. Locally, the climate forcing of aerosols and reactive gases can be larger in magnitude than that of greenhouse gases. Measures to improve air quality worldwide may release the 'aerosol brake', and foster the warming induced by greenhouse gases. Some aerosols like nitrates, ammonium, and mineral dust containing iron and phosphorus also exert a "fertilizing" effect over ocean and terrestrial ecosystems where they are deposited, generally increasing productivity. Increased productivity can result into more efficient CO2 sink, but can also yield to higher CH4 emissions by wetlands. In some instances, however, excess deposition of nitrogen will lead to decline of productivity in polluted regions, and sulfate deposition may inhibit CH4 emissions in wetlands.

The goal of WP1 is to coordinate and develop research on the evolution of atmospheric long-lived greenhouse gases, CO2, CH4, N2O and aerosols and reactive gases at IPSL, both for observations and for modelling. Specific focus will be given to interactions between aerosols and greenhouse gases, and the attribution of changes in biogeochemistry induced by aerosols, and in a second phase, by reactive gases as well.

Contribution to the mid-term key issues

Over the next 2 years, WP1 will focus on four main actions:

Action 1: Improved budgets of greenhouse gases and aerosols to reduce uncertainties on sources of radiative forcing over the globe, with emphasis on selected regions

We will use atmospheric inversion models, forward atmospheric chemistry transport models and observations to reduce uncertainties on key sources of radiative forcing for selected regions of interest, and underlying processes. As a contribution to mid-term issues 2, 3 and 4, Focus will be given to CH4 emissions in the Arctic from fires, permafrost, wetlands and anthropogenic activities, in linkage with the 'Chantier Arctique' national activities, the phase-A of the CNES-DLR MERLIN satellite mission, and using available in-situ (ICOS), campaigns (YAK, CLIMSLIP), and satellite observation (IASI, GOSAT). The second process investigated will be organic aerosol emissions and transport in the Mediterranean region (CHARMEX). The third proposed activity will analyze radiative forcing trends over Asia caused by multiple anthropogenic actions including emissions of greenhouse gases, land use change, reactive gases (NOx, Ozone) and aerosols emissions, and indirect effects of aerosols such as black carbon deposition on snow. This activity will also address the **evaluation** of the biogeochemical components of Earth System Models. For instance through participation to intercomparison programs and development of metrics for offline and coupled models performances.

Resources needed: funding for organizing 2 workshops, taking stocks of other projects

This action has taken place. Reporting will be done in the next action plan

Action2: Attribution of the radiative forcing of long-lived GHG, aerosols and short lived gases to underlying mechanisms.

We will use models to attribute observed global and regional radiative forcing changes to emissions and sink processes. This activity will first focus on the **interactions** between the biogeochemical cycles of climate forcing agents, in particular the climatic and biogeochemical (fertilizing) effects of aerosols and reactive gases on the carbon cycle and on natural ocean and terrestrial fluxes of CO2, CH4 and N2O (e.g. climate cooling induced by sulfate aerosols effect on land / marine productivities, the carbon cycle and atm. CO2). Specific focus will be given to the effect of climate,CO2 and aerosols on variability and trends of the productivity of marine and terrestrial ecosystems. This action will contribute to mid-term issue 2.

Resources needed: funding for inviting a senior scientist for 3 to 6 months in 2013 (LISA, LSCE, LMD) on aerosols and greenhouse gas interactions in earth system models (15 K). In addition, funding for a postdoc researcher during two years is requested (100K) between LOCEAN, LMD and LSCE.

The visit of N. Mahowald is scheduled for 2013 and 2014.

Action 3: Incorporation of the aquatic loop of the carbon and nitrogen cycle in the IPSL Earth System Models

The transport of C (DIC, DOC, POC) from soils to river headstreams up to the coastal ocean is a large global lateral flux of carbon, commensurate with the land and ocean sinks of atmospheric CO2. An increasing number of measurements are being collected for diverse river basins. We propose to incorporate a simple version of C (and in a second step N) transport by rivers into the routing scheme of the ORCHIDEE land surface model and to calibrate the global model with emission factors from soils estimated from data mining and synthesis of literature data (in particular regarding the age of exported C). The process of CO2 outgassing by freshwater systems and burial of C in lake sediments will be included in a simplified manner. Effects of land use and climate changes in the export of C and N from land to oceans will be studied for different scenarios, and used to force the ocean biogeochemistry model PISCES. The development of a higher resolution version of the NEMO-PISCES model, in the context of a collaboration of L-IPSL with the Labex-Mer, will greatly benefit to this action.

Resources needed: funding for a postdoc researcher during two years is requested (100K) between SISYPHE, LOCEAN, LSCE. Additional resources from other projects.

This action will start in Summer 2013 with hiring a post-doc researcher who will work with L-IPSL teams.

▪ *Work Package 1: The predictable part of climate for the next decades*

Main objectives and strategy

A large component of the recent global warming is now attributed to human activities. Global warming will continue during the next decades at a rate depending primarily on the anthropogenic emissions discussed in the previous section. However, the mechanisms and the respective role of internal variability, of natural or anthropogenic forcings on most aspects of recent climate changes (such as sea-ice decrease in the Arctic or precipitation changes in the Sahel) are currently not established. This lack of understanding limits our ability to predict climate evolution over the next few decades.

For the future, the predictability of regional climate for the next decades to century will primarily depend on: (1) the response to changes in long-lived greenhouse gases; (2) the response to regional changes in aerosols and other short-lived species; (3) the low-frequency modes of natural variability.

The goal of WP2 is to coordinate and develop related research at IPSL, both for observations and for modelling, with a focus on three related key objectives:

- Quantify and understand the internal and natural variability of climate**. Understand climate fluctuations (e.g. AMOC, ENSO, …), their dependencies on the mean climate state and their response to external forcings (GHG, sun, aerosols,…). A specific effort will be devoted to the study of the last millennium, a period for which decadal to sub-decadal climate variations may be reconstructed from various natural archives, and for which some estimates of forcings associated with solar variations and volcanic eruptions are available.**

- Quantify and understand climate changes due to anthropogenic forcing. **The primary mechanisms involved in the spread of climate feedbacks, in particular those due to radiative feedbacks will be explored in order to improve our estimate of the amplitude of climate change in response to external forcings. We will also investigate how climate parameters and phenomena (e.g. tropical precipitation change, AMOC, ice sheets dynamics, storms, heat waves,…) will change with temperature and forcings..**

- Predict and assess climate changes at decadal time scales. **Unravelling the respective contributions of external forcing and internal variability in the recent and future decadal change requires to (i) to identify and assess mechanisms that drive climate variability and trend and (ii) to increase our confidence in climate change projections. A joint development and use of global earth system models and observations will help both the detection and attribution of these decadal signals. The possibility to forecast the predictable part of the next decades will be explored using a combination of historical and initialised simulations. For such timescales, the slow components of climate models (ocean, sea-ice,…) need to be initialized near observations and the L-IPSL will seek to develop new methodologies and select appropriate observations. New approaches will include perfect model studies to better understand the mechanism at work in the models (beyond the issues related to model errors, lack of data, and the combination of different sources of external forcing over the last 50 years).**

Contribution to the mid-term key issues

Over the next 2 years, WP2 will focus on four main actions, contributing to issues 1, 3 and 5:

Action 1: The role of volcanic and solar forcing

Volcanic forcing has been shown to be a major driver of decadal variability and predictability both in recent decades and during the last millennium, in particular in the North Atlantic and for the AMOC (eg Booth et al. Nature 2012). Before this action, the physical and chemical representation of volcanoes in the IPSL model was too simplified to 1) explore the mechanisms by which volcanoes can provide a source of climate variability and 2) compare to the many related observations available at IPSL. The goal of this funded action is, first, to adapt an existing 2D model of the microphysics of stratospheric volcanic aerosols (LATMOS) to the 3D IPSL GCM (LMD) and, second, analyse the resulting simulations for the last decades and last millenium (LOCEAN, LSCE), with a focus on North Atlantic THC variability and predictability. The project has started since a year and below is a summary of the work undertaken and future plans. This action is also a contribution to TWP1.

In a first step, it was decided to align with the CCMI Protocol and data-sets to evaluate the coupling of the radiative impacts and heating rates deduced from LMDz (extinction coefficients, single scaettering albedo, and asymmetric factor) with the Chemistry of REPROBUS (Surface Area Density, mean radius, aerosol volume density) when including stratospheric volcanic aerosols and a coupled ocean. CCMI provides consistent datasets deduced for SAGEII satellite observations (1960-2011) as monthly zonal-vertical datasets (36° lat x 70 levels) for several wavelengths in the solar and terrestrial bands (see Eyring et al, SPARC Newsletter, submitted, 2012). Starting with these forcings will be a very useful benchmark to constrain LMDz-REPROBUS-NEMO model skills. The datasets from CCMI have been interpolated over the IPSL model 2 solar spectral bands and atmospheric model grid (M. Khodri, O. Boucher) and simulations are running. The results also have the ambition to help evaluate the robustness of the forcing deduced from the 2D microphysical model of developed at LATMOS (S. Bekki) to explicitly calculate these parameters for the 3 volcanic eruptions of interests (Pinatubo, Tambora and 1258). This second phase will be starting on July 1st with the hiring of M. Diallo as a Labex post-doctoral fellow.

Action 2: The use of observations of past decadal variability to validate models

The use of observations of past decadal variability to validate models, in particular the use of deep corals in the North Atlantic will be investigated. This will require synchronisation both in time and across variables in climate archives. The L-IPSL is uniquely placed to make significant progress in this area, initially involving experts from IDES, LOCEAN and LSCE. This action requires more meetings in the next year to mature into specific integrating action (cf HAMOC ANR, submitted).

The second aspect concerns the detection and attribution of decadal changes. This requires (1) the development of statistical methods expertise to detect changes in decadal variability both in observations and in models and (2) to distinguish two time horizons: 30-40 years for which the external forcing dominates and 10-20 year which requires initialised deterministic simulations. This specific task will be initiated via the invitation of an expert and the organisation of a workshop involving the IPSL statistical experts (SAMA group).

Reporting will be done on this action on the next update of action plan.

Action 3: Climate sensitivity, climate forcing and climate change amplitude

This action will seek to understand what are the mechanisms that primary explain the spread of climate feedbacks. The following mechanism will be explored: clouds, cryosphere, climate-carbon, etc. and how to estimate and access them. The sensitivity of climate change to different forcing agents and mitigation policies (GHG emissions, aerosols emissions, land-use,...) will also be explored (LMD, LSCE,…).

Specific integrating actions will include (1) the support of IPSL leadership in WCRP Grand Challenge on "clouds, circulations and climate sensitivity" and namely the invitation of experts and the organisation of a paleo-cloud workshop, and (2) the study of cloud-circulation feedbacks, especially in tropical regions, and using both recent past, future, paleo or idealized simulations simulations (CMIP5, PMIP3, CFMIP) within a postdoctoral project. Two one-year post-docs will be hired, starting in 2014 or end of 2013.

Action 4: Large-scale patterns of climate change and impact on climate phenomena

The large-scale patterns of climate change (global circulation changes, precipitation, weather regimes, storm tracks, drought, heat waves, etc.) will be analysed to infer what element of predictability they provide for the next decades, considering again two time horizons. The impact of climate change on climate phenomena (Monsoons, ENSO, etc.) will be specifically addressed (LMD, LOCEAN, LSCE,…). Specific integrating actions will be decided on the basis of several meetings.

Reporting on this action will be done in the next action plan update.

Action 5: Initialization methods for coupled climate models

The development and validation of initialisation methods for coupled climate models using both the historical set up and associated observation and a perfect model set up to understand mechanisms will be further developed for the IPSL model.

First results show the key impact of sea surface salinity nudging used in conjunction to SST nudging to reconstruct the sub-surface ocean decadal variability in a perfect model framework (Servonnat et al. Clim. Dyn. submitted). Beyond ocean initialisation, we will explore sea-ice and land surface initialisation. This action will be done via projects (GICC, ANR, EU) meetings and workshops.Beyond ocean initialisation, we will explore sea-ice and land surface initialisation. This action will continue to be done via meetings and workshops.

Links to other projects

The following projects will provide effort towards the WP2 actions in the next two years:

National: MISSTERRE (LEFE/IMAGO, CNRS/INSU), EPIDOM (GICC, end in 2013), ANR (Green Greeland, 2011-1014, HAMOCC, MORDICUS)

EU: SPECS (FP7, 2013-2017), EUCLIPSE (FP7, 2010-2013), COMBINE (FP7, 2009-2013), EMBRACE (FP7, 2011-2014).

- ***Work Package 3: Regional implication of global warming***

Main objectives and strategy

The overarching objective of WP3 concerns the characterization of the implications of global warming in terms of regional climate changes as experienced by the human societies is needed to make appropriate adaptation decisions. WP3 will focus on the existing strengths of L-IPSL in terms of expertise (the water cycle, the biogeochemical cycles, and their interactions) and tools (observatories, space-borne observations as well as global and regional modeling – CMIP5 & CORDEX). Enhanced knowledge on how regional climate can also impact global climate will be achieved by assessing the role of mesoscale and regional processes in climate projections.

Disciplinary advances regarding the comprehension of the processes responsible for the changes for key climatic variables currently observed, and their evolution as inferred from climate projections will be developed. The role of regional changes driven by local feedbacks (hydrological coupling, clouds, aerosols, land cover and land use, regional water bodies) must be addressed and weighted against the large scale processes (interactions with the ocean, greenhouse gases, tele-connections, …).

WP3 will benefit from the momentum created at IPSL by the international CORDEX exercise and participate to international intercomparisons, studies using model ensembles, with four regions of focus, where IPSL participates to CORDEX: Europe, the Mediterranean region, Africa and South America. From the corresponding simulations, a synthesis of issues raised within the exercises will be carried out and more general regional modeling bottlenecks will be identified.

WP3 will also provide capacity building for L-IPSL laboratories on climate change implications at the regional scale, as for instance advice on the use of projections on at regional scales and guidance for selecting model simulations and also improving models.

Contribution to the mid-term key issues

WP3 will provide a major contribution to Issue #3 “Changes in the precipitation regimes and water resources”, to Issue #4 “Fast warming and atmosphere, ocean, cryosphere feedbacks with a focus on the Arctic region” and to Issue 5 “The indicator factory”. Over the next 2 years, WP3 will focus on four main actions:

Action 1: Intermediate scales issue

As a contribution to Issue #3, WP3 will assess the relevance of high resolution modeling for the investigation of the regional implication of global warming at intermediate scales (i.e. scales covered by both global and regional models, 30-50 km). This issue is particularly critical for precipitation regimes over the Sahel region but also on other regions such as Europe, for which neither GCMs nor limited-area models are currently able to cover all concerned spatial scales. Regional models are designed to represent mesoscale processes and surface conditions more realistically than GCMs. However, since they are area limited they lack the climatic feedbacks at teleconnections present in global models. ***The overarching question is which type of model should be given more credit when applied at intermediate scales?*** Existing CORDEX runs will be used to assess the impact of dynamical downscaling on key climatic variables

(with TWP1 and TWP3) and impact indicators (with WP4) by comparison with CMIPS5 runs. Advanced knowledge will be gained through this exercise for instance on the necessity to guide or nudge regional models using global models.

The work for this action will be designed around models used at IPSL, i.e. regional limited-area models and the zoomed version of the GCM LMDz. Existing CORDEX runs will be used to assess the impact of dynamical downscaling on key climatic variables by comparison with CMIPS5 runs. We propose to focus on the representation in these models on key variables: (i) radiative fluxes (visible and infra-red), including forcing from aerosols and water vapor, (ii) PBL dynamics, in particular over the Sahara, (iii) heat & water transport across West Africa, (iv) heat & water budget in the monsoon region and in the Saharan heat low region. As a first step, the work is proposed for the period 1980-2010, to benefit from the wealth of data currently available. In a second step, the work could be extended to climate projections. Advanced knowledge will be gained through this exercise for instance on the necessity to guide or nudge regional models using global models. A 12- to 18-month post-doc position is currently planned for this work (to be recruited before mid-2014).

Action 2: Climate variables and indices for impact-oriented indicators

The aim is to build the bridge between the output of climate and regional models, on the one hand, and environmental variables that are relevant for impact assessment, on the other hand, whether they relate to the mean state of the environment (e.g. ecosystem productivity, water resources) or extreme events (e.g. frequency, intensity, persistence of floods, droughts, heat waves, blocking, cyclones). This will be achieved via brainstorming workshops with WP4. An attempt will be made to define the best indicators for a variety of impact studies covering a wide spectrum of applications, namely agriculture, water resources, renewable energies, pollution, health, food security, etc…

Once defined, CMIP5 downscaled by CORDEX regional runs with possible further statistical downscaling will be used to construct the above-defined indicators and analyze their trends. The analysis on impact indicators will be conducted is some key regions, namely West Africa, South America, the Mediterranean region and Europe, which are the regions for which CORDEX experiments were made at IPSL. This action will serve as a starting point to Issue #5, the indicator factory.

This action requires meetings for the definition of indicators (a first meeting is scheduled 27 June 2013) and the work of a post-doc (hired as of May 2013), in common with WP4 and TWP3 (see details in WP4 below).

Action 3: Development of a theory for land-ocean-atmosphere coupling on decadal time scales

Dust emitted from the Sahara and Sahel regions of Africa vary on time scales ranging from hourly to decadal, and influence the climate of the tropical and subtropical Atlantic via changes to the radiative budget at the surface through the top of the atmosphere. It is also known that the physical state of the Atlantic Ocean influences the regional atmospheric circulation, and thus the hydrological cycle over Africa. In theory these changes in the circulation and the hydrological cycle should affect dust emission, thereby establishing a regional coupling of ocean-atmosphere-land surface processes, but to-date no such coupled theory has been developed or tested.

We propose to identify the two-way relationship between regional climate variability and mesoscale

processes over the Sahara-Sahel region of Africa via a combination of observational analysis and modeling studies. This work will be conducted in connection with WP1, WP2 and TWP2. Specifically, we aim to answer the following questions: 1) How are the mesoscale processes that control dust emission from the Sahara-Sahel region related to the regional circulation? 2) How does decadal variability of the regional circulation affect these mesoscale processes and therefore dust emission? 3) Can we explain recent, and predict future, climate variability via development a theory that describes regional coupling of land-ocean-atmosphere processes?

This action has been fostered by the visit of Amato Evan (during initial LABEX phase, see above) and will contribute to Issues #1 and #3. The major research result stemming from this visit was demonstrate that, via the greenhouse effect, small changes in water vapor in the atmosphere over the Sahara Desert alter the thermodynamic structure of the Saharan Heat Low, thereby modifying the monsoon circulation and precipitation across the Sahel. We established that a "Saharan-Water vapor-Advection-Temperature" (SWAT) feedback is the fundamental mechanism controlling precipitation across the Sahel on long time scales, the dynamics of which is consistent with the synoptic-scale meteorology of the monsoon. Efforts on this action will continue on two fronts: (i) process studies underpinning SWAT feedback at decadal scales with a focus on the role of desert dust, and (ii) an analysis of the representation of the SWAT feedback in the CMIP5 and CORDEX runs for the period 1980-2010 (comparison with observations and re-analyses) as well as its evolution in the future using CMIP5 projections.

Action 4: Process level feedbacks and interactions in the Arctic region

Clear evidence for climate change is being observed at northern high latitudes in the form of diminishing summer sea-ice extent, thawing permafrost and changes in the Greenland ice sheet etc. Anthropogenic forcing, both local and remote, is clearly playing a role but complex interactions with natural physical and biogeochemical cycles in the atmosphere, ocean and cryosphere make changes in this region difficult to predict with current climate models. There a key aim will be to better understand the contribution of anthropogenic activities to Arctic climate change and the feedbacks between atmospheric composition/dynamics, and ocean, cryosphere processes. This will be tackled using a combination of high resolution modeling coupled to data analysis and make use of the Arctic data portal developed in TWP2. One aim is to better use existing datasets to evaluate regional/global climate model performance at IPSL in the Arctic region, a topic of importance noted at the recent Chantier Arctique colloque. Specific processes such as the impacts of aerosols will also be examined. A workshop will also be held to identify and develop cross-cutting research topics at the level of IPSL and in coordination with developments as part of the Chantier Arctique. This action will contribute to Issue #4.

For example, a first step towards enhanced knowledge of the processes impacting global warming at high latitudes will be undertaken through a synergetic approach involving observations and models, both in the laboratory (at L-IPSL) and in the field (e.g. Siberia).

This task has benefited from the visit of Steve Clifford in the initial LABEX phase, as well as that of Jerome Fast (PNNL) who visited LATMOS to foster collaborations in the field of regional chemical/aerosol modeling and aerosol-cloud interactions. This action will further benefit from the visit of Steven Reising (Colorado State University) who will stay in LATMOS for 6 months to work on atmospheric water vapor related process in the Arctic. Water vapor is the most abundant greenhouse gas in Earth's atmosphere, but it is the least accurately measured globally. The science questions tailored around Steven Reising's visit are: 1)

What quantitative information do observational data products provide regarding the trends of atmospheric water vapor with time, particularly in comparison with other quantitative measures of climate change impacts in the Arctic region? And 2) What is the reliability and quality of various sources of water vapor observational data in the Arctic? Steven Reising will work with water vapor remote sensing specialists at IPSL. In addition, comparisons will be performed with regional model simulations, global reanalysis and forecast products, and possibly CMIP5 simulations.

Links to other projects

On-going FP7, ANR, INSU, IRD projects in West Africa (non exhaustive): AMMA, AMMA-2, FENNEC, RIEPCSA, DRUMS, CAVIAR, contribution to "Chantier Arctique", possible IPSL lead for national projects, link with Labex BASC regarding the productivity of terrestrial ecosystems and agrosystems, and the feedbacks with the water cycle (irrigation, water quality). Other funded projects such as EU-ACCESS, EU-ECLIPSE and CLIMSLIP-ANR will also help structure of the work in WP3.

▪ *Work Package 4: Impacts*

Main objectives and strategy

We focus here on the impacts of climate change on the natural resources and the ecosystem services, the human activities they support and evolve with, and the resulting environmental changes. Regarding the future, an important issue is to characterize impacts in terms of vulnerability/benefit for resources and ecosystems services in order to propose sound adaptation strategies. The retrospective direction is also important regarding the detection and attribution of observed changes, and the necessary validation of models. An improvement in knowledge of processes in the natural environment including new process studies is needed in order to build forecast capacities for future impacts.

Such studies cover a very wide range of topics and require integrated approaches combining various data and models, with important issues regarding up/downscaling methods and uncertainty analyses, which will be addressed in tight collaboration with WP3 and TWP3. Based on the existing strengths of L-IPSL, we initially identified four sectors on which to focus our efforts: water resources (including ground water and hydrological extremes), biogeochemical fluxes and ecosystems along the land-ocean continuum (including terrestrial and marine productivity, water quality); energy resources and infrastructures; sources of regional and global air pollution.

A first WP4 meeting held on March 16th, 2012, helped to refine our scientific strategy. WP4 can rely on about 30 dedicated scientists from all L-IPSL laboratories, with different levels of experience regarding impacts studies, thus different kinds of actions depending on scientific expertise:

- **water resources, vegetation production: reinforce and integrate existing activities**
- **cold-processes/Arctic, terrestrial water quality and related fluxes, land-sea interface, marine ecosystems, air pollution: move from process studies to impact studies**

- **energy : develop the working force to continue preliminary results**

The L-IPSL budget cannot support all specific impact studies, and we rather aim at developing the potential of L-IPSL teams to attract their own funding, by promoting scientific structuration and methodological advances:

- ***Capacity building at IPSL on climate change impacts:*** **share experience on inherent difficulties; develop/adapt *ad-hoc* modeling capabilities to be responsive to research projects solicitations; promote supporting data-mining, observational & experimental work.**
- ***Cutting-edge methodological research:*** **disciplinary advances regarding overlooked aspects of the global cycles (*e.g.* land/sea fluxes, transfers and transformation in hydro-systems, marine ecosystems, ground water); interdisciplinary integration, including solicitations to climate modelers (WP3); adaptation strategies, in tight collaboration with TWP3 (Uncertainties) and the L-IPSL innovation activities.**

Contribution to the mid-term key issues

Over the next 2 years, WP4 will mostly contribute to Issues 2 to 5, via on-going research on involved environmental processes (biogeochemical fluxes and ecosystems along the land/sea continuum in Issue 2; water resources in Issue 3; cold-season processes in Issue 4, impact indicator in Issue 5). The mid-term contributions are largely focused on issues on which L-IPSL teams can benefit from substantial experience in either impact or interdisciplinary work. Yet, the three actions below are intended to interest a large spectrum of environmental scientists, as a lever to interdisciplinary capacity building on climate change impacts. These actions will also involve other work packages, mostly TWP3 and WP3 (Action 1 and 2), but also TWP1, WP1, and potentially WP5 on Action 3.

Action 1: Propose impact-oriented indicators

The aim is to build the bridge between the output of climate models (often biased multivariate 3D fields with a wide variability spectrum over centuries) and environmental variables that are relevant for impact assessment, whether they relate to the mean state of the environment (e.g. ecosystem productivity, water resources) or extreme events (e.g. frequency, intensity, persistence of floods, low flows, droughts, heat waves, blocking, cyclones). This will be achieved via brainstorming workshops, keeping in mind the need for societal appropriation by stake-holders of the devised indicators. WP3 and TWP3 will also be involved in this brainstorming, as the indicators must be easily deduced from regional climate model projections, and as a challenge is to convey information despite uncertainties.

This action has been launched with a dedicated workshop organized on June 27, 2013, targeted towards L-IPSL members, and selected representatives of stake-holders. The aim is to define the impact-oriented indicators to be effectively characterized in Action 2.

Action 2: Create a catalog of impact-oriented indicators

To demonstrate the interest of the above propositions, we will work at effectively characterizing the proposed indicators based on regional climate projections from WP3. A hierarchy of models (including the land surface model ORCHIDEE of IPSL and ocean models) will be used as a translator between climate

variables and productivity/hydrological variables. CMIP5 runs will be used to analyze their trends at the global scale, while CORDEX runs will be used to assess the influence of dynamical downscaling on these impact indicators. TWP3 will complement this catalog by documenting the uncertainties accompanying statistical downscaling methods. The ultimate goal is to create a starting milestone for L-IPSL impact studies, on which the entire impact community will then be able to build up. This action is an important contribution to Issues 3 & 5 (Water cycle & Indicator factory) and will be carried out by a 2-year post-doc shared between WP3, WP4 and TWP3. Note that characterizing the biases of the devised indicators under present climate ("validation") is an important aspect of this joint effort, for societal and scientific appropriation and uncertainty assessment.

In addition to the land-based (productivity/hydrology) indicators, we will develop ocean-based indicators through a collaboration with Labex MER. This could include (but is not limited to) indicators related to the state of marine ecosystems, or to the impact of climate change and sea-level rise on the coastal systems.

This action relies on the recruitment of a two-year post-doc shared with WP3 and TWP3, who started in May 2013. The work has been first oriented to the analysis of the ISI-MIP international project, with several impact models including the IPSL's land surface model ORCHIDEE, forced by downscaled climate change scenarios based on IPSL-CM5 and other climate models, The method to associate pertinent uncertainty to the indicators will be first established for NPP before being applied to the selection made in Action 1.

Action 3: Define the extrapolation power of impact models

Impact assessment relies on either conceptual or numerical models, which are both developed based on observations of recent climate. The transferability of such models under unprecedented climate condition is a crucial issue[1]. Our goal is to document, for a variety of L-IPSL models, climate ranges in which the models are supposed to hold, the larger ranges in which they might hold, and the thresholds over which uncertainty dominates, via workshops or questionnaires. Process studies will also be encouraged for documenting poorly-known relationships between hydrology/ecosystems and climate change.

Action 3 has not started yet, but the kick-off meeting is targeted for the end of 2013, to be followed by a "retreat" with hands-on work on the models.

Links to other projects

WP4 will benefit from many on-going or planned projects (FP7, ANR, GICC, GIS-Climat, FIRE, PIREN-Seine, MISTRALS, etc.), and interesting links will be developed with LABEX BASC regarding the productivity of terrestrial ecosystems and agrosystems, and the feedbacks with the water cycle (irrigation, water quality). The recent ISI-MIP project (Inter-Sectorial Impact Model Intercomparison Project, coordinated by the PIK) is a pioneer for international coordination of impact studies, and L-IPSL models will be encouraged to join this effort, following the ORCHIDEE land surface model.

[1] E. M. Wolkovich, B. I. Cook, J. M. Allen, T. M. Crimmins, J. L. Betancourt et al. (2012). Warming experiments underpredict plant phenological responses to climate change, Nature, 485: 494-497, doi:10.1038/nature11014

- ***Work Package 5: The risk of abrupt unpredictable climate evolutions***

Main objectives and strategy

Past climate archives have documented abrupt or non-linear changes, occurring sometimes in less than a few decades. These abrupt climate changes occur when the climate system is forced to cross some threshold, triggering a transition to a new state at a rate determined by the climate system itself and faster than the cause. Chaotic processes in the climate system may allow the cause of such an abrupt climate change to be undetectably small.

In order to properly address the risk of future abrupt climatic changes, the WP5 will conduct concerted efforts for the analysis and interpretation of high-resolution past climate archives, both on the continents (i.e. speleothems, lacustrine sediments, ice cores) and in the ocean (shallow and deep-sea corals, marine sediments), and will compare these data with models outputs (especially, proxy forward models) in order to better understand the causes, mechanisms and impacts of abrupt climatic changes, and take full advantage of paleo-archives to unravel potential climate crisis ahead.

Key efforts will be devoted (i) to understand the importance of mean, initial climate conditions on natural climate variability and abrupt climatic shifts, (ii) to identify and quantify thresholds, and (iii) to highlight potential precursors that could help us to predict the occurrence of future tipping points. (These *early warning signals* likely include changes of climate variability, whose study is therefore included in WP5 long-term goals).

Contribution to the mid-term key issues

During February and March 2012, a prospective discussion was launched within WP5 in order to identify top priority topics that should be addressed over the first 2 to 3 years of the L-IPSL labex. The **variability and abrupt changes in the North Atlantic** were identified as key aspects during this first prospective exercise (Issue 1). The importance of the North Atlantic area in terms of climate variability and predictability is readily explained by (i) its direct, regional importance for the climate over Europe, (ii) its potential sensitivity to climate warming through perturbations of the hydrologic cycle and the melting of the Greenland ice caps, (iii) its impact on global climate through perturbations of the thermo-haline circulation. WP5 will therefore contribute to addressing Issue 1 as stated above.

Four main actions were identified:

Action 1: reconstruct climate variability over the last millennia in the North Atlantic by using very high-resolution natural archives (i.e. ice records, speleothems, deep-sea corals, tree rings and marine sediments from high accumulation drifts) that make it possible to extend our understanding of natural climate variability beyond the instrumented period. This research topic lies at the interface with WP2. In order to discuss key issues and set up specific targets for this action, further discussion is needed.

The L-IPSL supported the organization of a congress on "Climate and Impacts", with a session dedicated to the state-of-the-art of rapid, Holocene climate variability. This 2-day congress, which was co-supported by PRES UniverSud Paris, UP11, IDES, LSCE and L-IPSL, took place in November 2012 and gathered more than

130 participants.

Action 2: better understand the risk of future abrupt changes in warm climates by analyzing and comparing high-amplitude climatic shifts under interglacial conditions. This topic covers the study of the Holocene, 8.2 ka cold event (timing, chain of events and quantification of water fluxes involved) and the comparison of Holocene and MIS5 variability in order to determine if abrupt or non-linear changes took place during past interglacials, under different conditions.

The L-IPSL allowed the definition of the ANR project HAMOC (intergrating IDES, LSCE and LOCEAN), which has been submitted, and will take up the challenges of improving present knowledge of the AMOC variability and links with the Mediterranean outflow and input of fresh water from the high latitude during the Holocene (abrupt or not, e.g. Medieval Warm Anomaly, Little Ice Age, 8,200 yrs cold event…). HAMOC will use state-of-the-art tools (geochemical tracers, chronometers...) and accurately dated cold-water corals and deep-sea sediments to reconstruct NE Atlantic and Mediterranean Sea circulation changes at unprecedented temporal resolution (<decadal to centennial). Paleoclimate reconstructions will be derived from rarely combined proxies of surface and mid-depth North Atlantic gyre and deep-water circulation. Data-model comparisons will be performed to explore the mechanistic links (forcing factors) between past climates and large-scale ocean circulation changes. In association to this action 2, a PhD has been launched to study the variability of the mid-depth hydrology of the North Atlantic through the use of a new tracer (εNd) analyzed in deep-sea corals and foraminifera that allows the reconstruction of past changes in water mass fluxes.

Action 3: unravel the mechanisms explaining the abrupt glacial variability across MIS3. The study of specific events and the comparison with proxy oriented model outputs are necessary to characterize past thresholds, test model responses, reconstruct the succession of events and identify the feedback mechanisms, which make it possible to bring back the system to its initial state.

This on-going issue is associated to an ERC project submitted in 2013. In association to this action 3, a PhD has been launched to study the variability of MIS3 through the use of a new tracer (Pa/Th) that allows the reconstruction of past changes in water mass fluxes. L-IPSL was a contributor of the First Open Science Conference of IPICS (Presqu'îles de Giens, October 1-5 2012).

This action (as well as Action 1) requires the improvement of synchronization between various paleoclimate archives. This chronology issue was discussed during a dedicated session of the "Climate and Impacts" workshop in November 2012. The first step of a specific action supported by L-IPSL will deal with improvement of the DATICE tool, which allows improving age models and the synchronization of climatic records based on advanced bayesian methods. This will be achieved through a post-doctoral work starting in August 2013, supported by L-IPSL. The young scientist will efficiently adapt this software to other climatic archives and will train paleoclimatologist to its use. This work is conducted in close collaboration with LJK, a Grenoble-based laboratory on applied mathematical methods.

Action 4: explore the risk of future massive destabilization of the Greenland and Antarctica ice caps. Precious information on the maximum rates of ice-sheet melting is contained in the records of past sea level changes. In order to extract all the climatic information and explore the risk of future massive destabilization, realistic models of ice cap dynamics will be coupled to regional models or zoomed global

models.

The implementation of models of ice cap dynamics (i.e. grizzly) is under progress. A workshop should be organized by the end of 2013 or beginning of 2014 to discuss the state-of-the-art of action 4 and define the pending mid-term actions.

In general there was a consensus among the WP5 community about the priority – for all WP5 main actions – of (i) improving *past hydrological cycle reconstruction and water fluxes*, and (ii) *developing precise, integrated chronologies*. These are the two main actions supported by L-IPSL WP5 (see TWP2 also for (i)).

Links to other projects

Two proposals were recently submitted to ANR: HAMOC (Holocene North Atlantic Gyres and Mediterranean Overturning dynamic through Climate Changes); MA CHRONO (Multi-Archives integrated CHRONOlogy). Results about these proposals are not known yet but should be soon released (june 2013). On-going data-oriented or modeling projects at the European level or national level (NEEM, EMBRACE, COMBINE,…).

▪ *Transverse Work Package 1: Numerical modeling of the climate system*

Main objectives and strategy

The ability to better understand and to anticipate the climate change over decadal timescales and beyond depends for a large part on major developments and improvements of the predictive capabilities of climate models. In the absence of established analogues of greenhouse gas-driven climate change, numerical modelling based on a physically-based representation of the key processes and components that govern the dynamics of the climate system is increasingly recognized as the most valuable approach to anticipate future climate change, at both the global and regional scales, and to improve the predictive capabilities of climate models. IPSL has progressively developed a comprehensive Earth System Models (ESM), with a leading position in many of the relevant aspects (such as ocean modelling, carbon-climate coupling, cloud feedback studies, paleo-climate simulations...). The three main objectives of this transverse work package are (i) to provide simulation results and to carry out specific simulations to “feed” in the other work packages, (ii) to undertake specific developments that help the other work packages, and (iii) to continue to develop the IPSL climate model to maintain the IPSL Earth System Models (ESM) as world-leading.

In view of these major scientific and societal concerns, L-IPSL will focus on three related key objectives:

- Improving the representation of physical processes and their couplings: **The inclusion of new interconnected components (carbon cycle, chemistry and aerosols) into climate models and the need of more reliable regional climate-change projections require improved representations of the basic physical processes. Special efforts will be made to improve the representation of cloud-convection-turbulent processes, the hydrological cycle over land, coastal upwelling and ocean vertical mixing at high latitudes,**

coupling between atmosphere-ocean and cyrosphere, aerosol-cloud interactions, fast coupling between atmosphere and ocean, and to increase the resolution of the models.

- Improving the representation of aerosols and biogeochemistry processes and their coupling with physical processes**: To better represent the ability of natural sinks to absorb anthropogenic CO_2, key processes will be included and improved (land-vegetation phenology, phytoplankton physiology, carbon-nitrogen cycle interactions) in the terrestrial and oceanic carbon cycle models. Beyond CO_2, other climate forcing agents (aerosols, methane, ozone, N_2O…) will have to be more explicitly represented, which requires both interactive atmospheric chemistry and representation of biospheric fluxes (e.g., oceanic DMS or VOC production as well as methane production by anaerobic soil respiration).**

- Developing new algorithms and models to take advantage of new computer performance: **Increased computer power in the coming years is expected to come from new architectures and an increased number of CPUs. A major effort will be made in rewriting the "dynamical cores" of the atmospheric and oceanic models, using new approaches (e.g. finite volume on "cube spheres" or "icosahedral grids"), in developing new tools for the Inputs-Outputs and model infrastructures. The increased power will enable increased model complexity, resolution, and the number or length of the simulations.**

Contribution to the mid-term key issues

TWP1 will develop tools and provide support that will contribute to the five issues. The following specific actions are proposed for the next 2 years:

Action 1: Working towards high resolution versions of the IPSL Earth system model.

This goal will be achieved through work in three main areas: (i) increasing resolution of current version of the atmospheric model and adapting the parameterizations accordingly, (ii) developing new tools for high performance input-output and testing them with the oceanic model and (iii) rewriting the "dynamical cores" of the atmospheric model using finite volume approaches on "icosahedral grids".

Reporting on this action will be done in future Action Plan versions (no LABEX funding yet)

Action 2: Development and better integration of the various cycles.

All model components have a representation of the water isotopes, but the full integration in the global coupled model has to be done. The current aerosol model is comprehensive but the effect of aerosol deposition on the carbon cycle, vegetation and cryosphere needs to be included. The nitrogen cycle also needs to be integrated across the different model components (chemistry, ocean and terrestrial carbon cycle).

Reporting on this action will be done in future Action Plan versions (no LABEX funding yet)

Action 3: Development, adjustment and evaluation of the versions of the IPSL Earth system model.

New developments have been made respective to the IPSL-CM5 model used for CMIP5 that should

significantly improve the characteristics of the simulated climate: update of the atmospheric convections, new land hydrology, increase of horizontal and vertical resolution for both the atmosphere and the ocean, etc… In addition, the adjustment of key coefficients of the parameterizations is now recognized as a key phase of the development process of climate models. A new version of the IPSL ESM will be developed, tuned and evaluate. It will constitute a "beta" version of the model version that will be used in the next phase of CMIP.

A post-doc will be hired in 2014 to help the development and the tuning of the new version of the IPSL-CM model.

Action 4: Development of a stretched version of the IPSL Earth system model.

LMDZ, the atmospheric component of the IPSL model, has a stretchable longitude-latitude grid that allows grid refinement. To transpose this capability to IPSL-ESM, it is necessary to develop general tools to interpolate gas and dust emissions on the atmospheric grid and to interpolate any data on very fine grids.

This action, already decided and funded in 2012 was delayed. An engineer will be hired in 2014 to help to develop this stretch version of the IPSL model.

Action 5: Facilitating the distribution and analysis of CMIP5 and related projects

The CMIP5 model outputs constitute an exceptional database used by climate centers to investigate the climate, climate change and the impact of climate change. Many related projects have now adopt the same data-base system and convention as CMIP5.To fully benefit from this database, an infrastructure has been implemented by IPSL that includes a very large storage capacity and computing resources relevant for the analysis of large datasets. New tools will developed in order to facilitate the analysis of this very reach data-base that is expected to feed many research questions during the next years.

An engineer has been hired to help publishing and to document the CMIP5 results for the IPSL models, to correct the detected errors and to document the various errata. He will also develop tools to facilitate CMIP5 analysis and document them. To facilitate the analysis of the CMIP5 data, additional disk space has been bought to increase the storage space (currently 400 To).

Links to other projects

National:

- MissTerre (LEFE/IMAGO, CNRS/INSU)
- Dephy (LEFE/IMAGO, CNRS/INSU)
- EPINES (Mastodons/CNRS)

European

- COMBINE (2009-2013)
- EMBRACE (2011-2014)
- IS-ENES 2 (2013-2016)

- SPECS (2012-2015)

ANR

- CONVERGENCE (2013-2016)

▪ *Transverse Work Package 2: Data management*

Main objectives and strategy

Observations for monitoring climate changes require long data sets including instrumental measures and paleoclimate proxies. Available series of observations and proxies are strongly inhomogeneous in nature, length, observed parameters, location, sampling, resolution, requiring adjustments, corrections … and always correspond to a partial view of the climate systems. One strategy for taking advantage of these measurements consists in comparing them with numerical simulation outputs that give a more global context. Another strategy consists of simultaneously collecting many different types of data to better understand processes. Finally, innovative instruments and methods are required to access new measurements that help to characterize climate changes and constrain models. Preliminary tasks consist of identifying, collecting, qualifying, correcting, coupling, and formatting these series to insure a better use of these data with models. The attribution to climate changes on long-term series of measurements as well as numerical simulations requires both sophisticated statistical analyses. The L-IPSL LABEX proposes to complement and insure a better coordination with the thematic national data centers like ETHER or ICARE, respectively for atmospheric and aerosol composition respectively. IPSL teams already collect a lot of data that are not easy to use for evaluate models. IPSL has setup the ESPRI structure for coordinating data handling for both observations and model outputs (Prodiguer-CMIP5 project). The expertise on innovative techniques can be further increase with a better coordination across the LABEX partners.

One of the main goals will be to provide accurate reference observations available for direct observations with numerical models and associated statistical analyses. For such purpose, new innovative measurements and data series analyses will be developed. One example is the use of water isotopes to compare model outputs with field measurements and/or paleo-proxies through proxy-forward models.

Contribution to the mid-term key issues

Action 1: Water stable isotopes database and working groupe

Water isotope ratios in rainfall and paleo-proxies (ice, carbonates, organic molecules) provide information about the history and circumstances of water precipitation (transfer, phase change, temperature, convection, precipitation, evaporaton). This is complex but useful information for understanding atmospheric, continental and oceanic cycling of water for both actual measurements and paleo-climate archives. While isotopes are already include in the IPSL Earth model, this LABEX action is a good opportunity to compare model and observations. Two tasks are proposed:

- The first one consists in collecting existing $^{18}0$, $^{17}0$ and D data series in a database to allow direct

comparisons with model outputs in the framework of CMIP5/PMIP3. This action may concern the instrumental series, the most recent (last centuries) proxy-data (tree rings, speleothems,…), the best continuous older records and those centered on CMIP5 periods 6k and 21k. This database will be developed in coordination with the IPSL data management team (ESPRI).

The second task consists of forming a specific working group, on water isotopes in a first stage, then other isotopes might be included, with the objective to start the building of the database, to promote and improve methodologies (reports, courses), the model/observations comparisons, to promote the data base use in L-IPSL WP actions and to design campaigns using Picarro spectrometers and other measurements dedicated to water cycle investigation, in different domains.

Resources needed: funding for organizing a workshop

Action 2: Climate data availability and statistical analyses for climate attribution

Time series of both numerical experiments and direct observations include a large inter-annual variability. For future projections based on past data, and for the attribution, it is important to be able to analyze the variability and identify their causes. Available data need to be identified and shared. This can be done through a "climate portal" indexing the contact people and the archived database. A demonstrator that could be used for many other data sets will be soon available. Sophisticated and robust statistic methods need to be developed. The relative reduction of the ground temperature increase observed during the last decade or the solar signature could be good candidate for such investigations. Such a group already exists within IPSL: SAMA. Within the LABEX, it is proposed to organize dedicated workshops to share the expertise and present some of the challenges corresponding to specific LABEX issues. This action will be coordinated with WP2.

Resources needed: funding for organizing a workshop.

Action 3: Arctic data portal

A data portal linking existing observational datasets at high northern latitudes leading will be created to add value in terms of new data analyses and model developments and which would also be useful for the IPSL global modeling community. The LABEX Arctic data portal will be complementary to and builds on/ contributes to other national efforts. In particular, this initiative would be carried out in collaboration with the OVSQ Arctic Network and will use existing data infrastructure ESPRI. Sources of data from other institutes need to be identified and direct links provided in the portal. This action also belongs to WP1 and 3. The "Chantier Arctique" prospective was a good opportunity to identify the potential partners. A meeting is planned to discuss, among the Labex partners, the collaborative work including the links between observations and modeling studies. The process of hiring a postdoc fellow to carry out this action is on-going.

Resources needed: funding for organizing a workshop, invite a senior researcher working on coupled issues related to Arctic climate change and evaluation of climate model performance in this region.

Action 4: Lidar strategy

IPSL has developed a strong expertise in lidar technology. Many applications for ground network, onboard planes, and from space, are envisioned. All these proposed instruments are different but are using similar expertise. To conduct an optimal development of the future innovative instruments, dedicated workshops have been held and will continue. A strategic document has been written. A powerful 3-wavelengths lidar to measure the aerosol size distribution from ground to the tropopause was designed and funding partners identified. The next project will concern the water vapor airborne lidar. This action will be coordinated with WP3. Within the LABEX, attention will be paid to GES observations. This action will be coordinated with WP1.

Resources needed: invited senior researcher expert in lidar and other waper vapor techniques

Action 5: development and shared use of analytic platforms

Climate change research will benefit from the coordinated use of the existing platforms.

- Most of the IPSL laboratories benefit from their location in or around Paris to develop observations related to air composition. The large spread of their implantation at different locations provides a valuable network that needs to be coordinated. This will enable the study of local emissions in the Paris megapole on regional air quality and global atmospheric composition.

- Another area concerns analytical laboratory instrumentation within L-IPSL laboratories. The build-up of such coordination, for instance in LSCE and IDES, has started and was supported within the initial phase of LABEX. The LABEX will help to further develop shared use of these platforms within LABEX laboratories, and to coordinate efforts with other instruments in other laboratories.

Resources needed: invited senior researcher expert in air quality

Links to other projects

The isotope working group will benefit from the ongoing experience of Wsibiso project (combination of satellite measurements, FTIR, Picarro and GCM outputs for Siberian region – J. Jouzel). The introduction of water isotopes in the Oceanic Model is being realised through the Past 4 Future project (J.C. Dutay). The group is also involved in the ISOTROPIC ANR project, designed to better understand water cycle and related coupled modeling uncertainties through water vapor isotope measurements. The Arctic data portal work at L-IPSL will be linked to national efforts related to the Chantier Arctique and to international data catalogs.

- ***Transverse Work Package 3: Assessment of uncertainty in climate diagnostics and projections***

Main objectives and strategy

The objective of this transverse work package it to strengthen strategies and methodologies across the different WP for assessing the uncertainties associated to climate diagnostics and projections. The work is divided into two major tasks. The first one will make use of scientific expertise developed in the different WP to improve the characterisation of the cascade of uncertainties from the climate forcings to the regional climate response focussing on model skill and the understanding of model uncertainties. The second will provide the scientific ground, climate indicators and methods that are needed to characterise the uncertainties in the different model outputs and to evaluate climate indicators that are used in impact or adaptation studies. New scientific developments are needed to achieves these goals and the outcome of this TWP will be of direct use to define the innovation and expertise transfer strategy related to the dissemination of key results on climate change and variability.

This requires to:

1) gather the key analyses and methods used to characterise the uncertainties in the different WPs;

2) develop a common expertise to qualify and quantify the uncertainties considering the different sources of errors inherent to model structure, experimental protocols used to run climate simulations, downscaling strategies or statistical analyses;

3) offer a forum to discuss model evaluation considering both large scale and regional scale simulations, including specific targets on user oriented questions.

In the long term this will provide:

- **A quality assessment of the IPSL climate projections considering large scale and regional simulations (linl with WP2 and WP3, TW1 and TW2)**
- **A suite of key diagnostics and examples to qualify, quantify and understand model uncertainties, including a focus on variables of interest for impact studies and adaptation (all WP and TW1)**
- **A documented catalog of methods to assess model results depending of the scientific objectives (WP2, WP4)**
- **An analyses of the sources of uncertainties of the suite of climate indicators computed from climate simulations or from impact models (link with WP4) that will be distributed and used to characterize the impact of climate change on the environment of society**

Contribution to the mid-term key issues

For the next two years the focus will be on the characterization of model performances and uncertainties in the different analyses performed along the 5 major issues identified to be the major mid-term focus of the LABEX.

Action 1: Development of new methodologies using multi-model ensembles

Several gaps have already been identified in the IPSL community concerning the use of different types of model ensembles. A first action will be to share the different practices across the work packages. This also includes the specific analyses of model ensembles needed for decadal prediction as part of WP2. There is thus a need to organize specific seminars and internal workshops for large scale diffusion and common development of new methodologies.

Reporting on this action will be done in the next action plan (no LABEX funding yet).

Action 2: Gather key diagnostics for model evaluation

Model evaluation is a key component of the estimation of uncertainties. An objective is to gather the key diagnostics that are used in the different work packages so as to build a suite of evaluation tools that can be used to assess different aspects of the climate system. This task is common with similar activities in TW1. TW3 will in addition, contribute to the transfer of expertise that needed to be provided with the model results as part of the IPSL model results distribution strategy.

Reporting on this action will be done in the next action plan (no LABEX funding yet).

Action 3: Identify and diffuse best practices and statistics

Statistical methods play a key role in climate analyses to isolate modes of variability or extreme events, or in downscaling and corrections of model output to be used in impact studies. This activity is spread in different projects and an objective of TW3 will be to organize the return of expertise and the diffusion of the best practices across the WP. This will be done in collaboration with all the WPs. Key topics to be discussed across the work packages will be defined with the help of the research committee. A first priority will be given to downscaling methods and on methods used to isolate and correct model biases.

Reporting on this action will be done in the next action plan (no LABEX funding yet).

Action 4: Estimate and understand uncertainties in key climate indicators

The growing use of model simulations for impact studies or the development of adaptation strategies requires new developments in the way model results are provided to the other communities and in the presentation and scientific discussion of the different uncertainties. The production of climate indicators in WP4 will serve as examples on which specific assessment of uncertainties will be performed. Cross meeting will be organized between WP2, WP3 and WP4 to discuss uncertainties at the regional level and to specifically assess how model reproduce the key indicators that will be developed in WP4. This will be achieved through a post-doc position open, coordinated with WP3 and WP4.

This action is conducted jointly with WP4. A 2-year post-doc was hired in Spring 2013.

Action 5: Assess the different sources of uncertainties

Clear assessments of the results that are provided to other communities are needed. However it is difficult to find its way in the numerous sources of uncertainties, their characterization and their impact on the final

result. In a first step TW3 will foster the synthesis of ongoing work and prepare a work plan concerning the different scientific action needed to tackle these new subjects. This will be done through the participation of IPSL members to different international and national projects and meeting and the organization of small IPSL workshops. The first year will be used to establish the catalogue of key emerging scientific questions on these topics and the level of implication of IPSL LABEX.

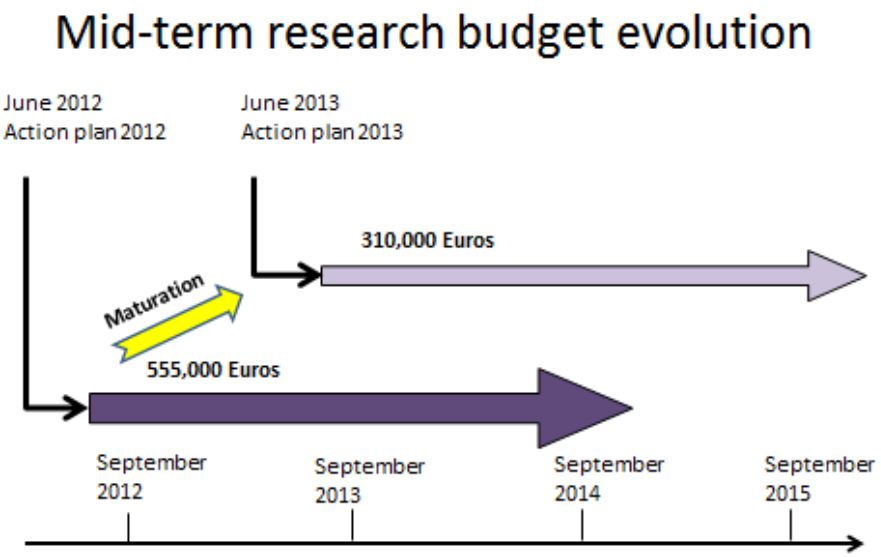
Reporting on this action will be done in the next action plan (no LABEX funding yet).

Links to other projects

IPSL members are already involved in European or national projects in which some of the points listed above are developed. The value added of TW3 would be to organize the return of expertise of these projects and to propose more perennial activity. It will also help to identify questions and results that will further benefits from a transfer of expertise as part as the labex valorization strategy. Interactions with IS-ENE EU e-infrastructure and DRIAS project for the understanding of user needs and the identification of gaps in research activities.

2.4 Research: Provisional Budget for the mid-term

The LABEX budget is proposed on a yearly basis with a 2-year perspective. This is illustrated in the figure below. Projects that are mature have a proposed budget in the 2012 mid-term action plan, to be decided before July 2012. Less mature projects requiring a few months of brain storming (during Fall 2012 and winter 2012/2013) and have an envisaged budget here. A new research budget proposition will be made in Spring 2013. Projects envisaged for starting in 2013 can be matured and will be budgeted in the 2013 action plan.



The 2012 action plan included a budget of

- **30,000 euros for animation, internal workshops etc… for the Sep 2012 – Aug 2013 period**
- **525,000 euros for research actions. The nature of expenses mostly consists in salaries (post docs, ingeneers) and invitations (travel and stay).**
- **An indicative budget of 245,000 euros for actions to be decided in Spring 2013 was envisaged. The proposed budget is 310,000 euros is actually proposed. It also includes 30,000 euros for animation and workshops.**

The table below summarizes the proposed funding for mature actions for the mid-term research action plan. Actions proposed for funding (orange lines when decided in 2012 and blue when proposed in 2013) are distinguished.

Proposed funding and laboratories involved	Dates / schedule	WPs	Mid-term Issue	Proposed budget in 2012	Proposed budget in 2013
1 Year post-doc for the development of a data base on Water Isotopes IDES/LMD/LOCEAN/LSCE	Jan --> Dec 2013	**TWP2/WP5**	**Issue 1**	**45**	
1 Year post-doc for the development of multi-archive, integrated age models. IDES/LOCEAN/LSCE	Mid 2013 --> Mid 2014	**WP5**	**Issue 1**	**45**	
2 Year post-doc to study the role of volcanism in the last millenium LATMOS/LMD/LOCEAN/LSCE	2013 and 2014	**WP2-WP5**	**Issue 1**	**90**	
2 Year post-doc to study the changes in the C transfer between land and ocean in the Arctic region LOCEAN/LSCE/SISYPHE	2013	**WP1-WP3-WP4**	**Issue 2 and 4**	**90**	
1 Year Engineer to develop the Arctic data portal ALL	2013	**TWP2-WP3**	**Issue 4**	**45**	
Iinvitation of expert for the development of time of emergence indicators LMD/LOCEAN	2013	**WP2**	**Issue 5 and Issue 1**	**15**	
2 Years post-doc development and evaluation of indicators ALL	2013 and 2014	**WP4+WP3-TWP3**	**Issue 5 and Issue 3**	**90**	
2 years engineer model to facilitate model results analysis and to set up new IPSL-model configurations	2013 and 2014	**TWP1**	**Issue 1,2,3,5**	**90**	
Invitation of an expert on cycles interactions	2013	**WP1**	**Issue 2**	**15**	
Workshops and animation 2012-2013		**All**	**All**	**30**	
1 Year post-doc on Grand Challenge issues on LGM and future climate sensitivity, and paleo-cloud workshop	2013 and 2014	**WP2**	**Issue 1**		**50+10=60**
Invitation of Scientists in the framework of the WCRP Grand Challenge	2013 and 2014	**WP2**	**Issue 1**		**20**
2 Year post-doc regional modeling of the intermediate scales in West Africa, and cloud–circulation feedbacks WCRP GC on climate sensitivity	2014 – 2015	**WP2-WP3**	**Issue 1 and 3**		**100**
Visit of scientists on water vapor observation over the Arctic region and on PBL (SIRTA)	2014	**WP3**	**Issue 3 and 4**		**15+5=20**
1 year post-doc (co-funded LABEX MER)	2014	**WP1**	**Issue 2**		**25**
1 year post-doc support to IPSL model development and tuning	End 2013 - End 2014	**TWP1**	**Issue 1,2,3,5**		**55**
Workshops, animation for 2013-2014					**30**
Total				**555**	**310**

3. Innovation and expertise transfer

Climate research teams – and in particular IPSL – have built scientific knowledge and technical tools that is transferable beyond the sole realm of research. A stronger and more integrated link between climate science and society is therefore required to build this transfer. This will steer employment for students, further use of IPSL science in many domains, and new scientific questions, sometimes fundamental from downstream applications. The L-IPSL needs to design an adequate strategy to spread climate knowledge and the associated tools and services, so that (1) it makes sure that its evolving expertise and the associated uncertainties and limitations, are fully taken into account, but also that (2) dedicated new structures are set up to provide the necessary help to confront a huge demand which is well beyond the capacity of L-IPSL alone. This strategy requires involvement of the scientists.

The capacity of L-IPSL to transfer knowledge and innovation concerns several domains:

• **Innovative instrumentation for environment observation and monitoring;**

• **Innovative modeling for environment prediction;**

• **Distribution of climate information and associated uncertainties;**

• **Advanced mathematical (for example statistical) methods to combine observations and model results for monitoring, forecasting; downscaling or uncertainty assessment.**

In each case, a specific strategy for innovation and the creation a value is needed. The strategy of the L-IPSL will be twofold:

- **to develop autonomous initiatives, relying on its strengths, or those of its sponsors to develop training programs with the universities or communication actions toward the public ;**
- **to develop a stronger partnership with industries and SMEs and use them as vectors of Knowledge transfer, in particular through non-academic partners.**

3.1 Innovative Instrumentation

L-IPSL scientific priorities concerning the monitoring of climate require the development of instrumentation for all possible platforms: ground based, airborne, within the ocean, from balloons or ships, from space missions. The observational strategy implies to monitor key parameters on the long term, with multiple parameters being observed and analyzed at collocated instrumental sites. The continuous development of innovative instruments and analyses is absolutely necessary to calibrate the measurement networks, increase their reliability. This part will be addressed by TWP2. It naturally leads to a transfer toward SMEs or larger companies. This transfer is necessary for long-term climate monitoring, which require development and operations of series of identical instruments, with operator institutions that are not

necessarily within research teams.

The figures present a few of major instrumental L-IPSL facilities, lidars, mass spectrometers, as an example of past IPSL instrumental use or development:

Based on developments of prototypes by research laboratories, transfer of knowledge is necessary to ensure this long-term observing strategy. The objectives of L-IPSL will be to transfer a few instruments or part of instruments or innovative algorithms or methods.

In the action plans for the first 3 years, one of the task will be:

- **to choose the instruments which could be transferred to industry. First of all, the criteria of our choices have to be defined. A selected strategy for the most mature instruments (lidars, analytic plate-forms..) will be defined taking in to account in particular the results of the working group of the technical directors of the laboratories. to further develop strong existing links with industrial partners, a network of SMEs and Public agencies. In the framework of the L-IPSL, we will reinforce or organize relationships by building a network and built procedure on expertise/ "advisory for instrumentation, algorithms for SME , industrial companies. The l-IPSL will also implement tools to help researchers to find financial supports (ANR ,SESAME, Kic CLimat).**

In 2012 2013, L-IPSL activities have been the following:

- **Lidar instruments: L-IPSL will help the development of new generation for aerosols and H2O lidars. This is a Common action with TW2. The strategy will be from one side to start a new innovative lidar system development for the atmospheric water vapor measurement with several objectives: answer to research, on a middle term a transfer to industry to answer to the requirement of continuous observations both for operational network and research climate observatories). On the other hand, within two years, high performances multispectral lidar observations will be performed continuously as long term observations.**
- **An innovative instrumentation committee has been implemented. The first meeting allowed to have an panorama of IPSL activities. The type of activities could be splinted in instrumentation, codes and**

algorithms. In 2014, the committee will decided for each type of activities those which could be transferred to industry for benefit of IPSL. Business studied will be planned.

3.2 Modeling and innovative methods

For modeling applications, the general strategy of L-IPSL will be to favor the use of its codes through open access, and help develop specific applications with SMEs, agencies and other industrial partners, through specific pilot projects whose products could be spread or commercialized. These specific applications will then be spread in a commercial mode for users via the SMEs and industrial partners. The offer of service concerning model studies should not concern the codes and the data bases only, but also the transfer of information and expertise for an optimized use. This will be favored by the organization of a user community (involving other academic laboratories, industries, SME or public decision makers), that will also use by themselves some of the offline components or impact models, thus providing incentive for an easier access to simulations, more explicit documentation.

3.3 Distributing the results of climate research, projections and their uncertainties: climate services

Distributing the results of climate research and specifically climate projections for adaptation needs constitutes a new mission for institutes such as IPSL. This distribution is now an international task, in particular through the IS-ENES / IS-ENES2 projects. Data produced by the CMIP5 and CORDEX experiments amounts are huge (1 Petabyte for the sole IPSL model in preparation of the next IPCC AR5 report). The complexity of the task should grow by one order of magnitude every 5 years. Distribution uses standardized international technologies, because the international community is evolving from the use of a central facility to the development of an International distributed database, for which IPSL will be a distribution node.

In 2012-2013, a strategic committee for climate services ("cellule de mobilisation pour l'information climatique") was set up. It has developed a climate service strategy (see draft version in Appendix 2), designed to be coordinated at the national level with METEO-FRANCE and CERFACS, and at the international level through the participation to a network of European climate services and various COPERNICUS projects. The strategy relies on four mandatory components of a climate service:

- **Climate projection data distribution, including uncertainties**
- **Access to expertise**
- **Development of prototype projects with users and SMEs**
- **Development of methods, tools and softwares**

Data distribution will be done in particular through the development, in coordination with Meteo-France, of the two data portals DRIAS and PRODIGUER, together with other institutional partners. The coordinated services that could be offered (the national strategy is still under development) by the two portals are:

- **DRIAS, lead by Meteo-France, will address national issues and a large variety of users with refined climate projections over France**
- **PRODIGUER, lead by IPSL, will address global to regional issues, with a more research-oriented approach, including an "analysis service", allowing access to a computing power, where users could develop their own analyses of climate projections.**

The L-IPSL will feed the DRIAS portal by developing and using downscaling techniques in order to produce climate projections at the scale of the French territory.

The main elements of the strategy can be summarized as:

- Strengthen the PRODIGUER portal so it can face the growing demand on climate data: **This will be done using existing resources and through the hiring of an engineer with INSU funding**
- Collect information on all existing L-IPSL projects and software with climate services objectives and developing a specific IPSL portal on climate services projects: **This will be done using existing resources.**
- Construct national-scale downscaled new data sets from CORDEX and/or CMIP5 to feed the DRIAS portal: **This will be done in support of the update of the "Mission Jouzel report" and from MEDDE funding. A post-doc is being hired for this.**
- Construct several added-value reference data sets (bias corrected data, indicators): **This will be done using existing resources and LABEX resources starting in 2014.**
- Develop a few starter projects with SMEs: **This will be done through a call for small projects in 2013, with LABEX funding and co-funding.**

In addition, the way L-IPSL and international climate and indicator data for adaptation services could be distributed will be discussed and defined within the new Climate KiC project Climate Data Factory. This project will help design such a service and define IP rules and potential market.

The involvement of researchers, engineers in this climate service approach and the strategy for the access to expertise will be defined through discussions in several meetings at the L-IPSL and national levels.

There are currently several programs developing interdisciplinary projects (GIS Climat Environnement-Société, GICC, Climate KiC, FP7 projects, …) for prototype use of climate services. At European level, a particular link to the IS-ENES project and related data portals will be set up. Copernicus projects CLIPC and EUCLEIA will help design pre-operational climate-change services on climate data and extreme events interpretation and attribution. New ways of supporting such actions may be discussed at the national level, within the strategy that will take place in the framework of the Alliance ALLENVI.

3.4 Budget

The initial budget for 2012 was dedicated to support:

- **"chargé d'affaire" to initiate valorisation**
- **Lidar instrumentation**

- **Informatic equipement to reinforce IPSL network and climate data storage**
- **Support to data analysis**

To implement the action plan 2013 – 2014, a provisional budget of 276000€ has been decided. The table below summarizes the initial funding for 2012 and the proposed funding for 2013-2014

2011-2012	Budget estimé	CDD	Equipement	Missions	Autres	PME	Total Dépenses
Ir Valo		24476		1389	2300		28165
TOTAL VALO GENERIQUE		**24476**		**1389**	**2300**		**28165**
Lidar			62577			35121	97698
TOTAL VALO INSTRUMENTATION	**100000**		**62577**			**35121**	**97698**
infra réseau			52182				52182
baie info			39000				39000
TOTAL VALO EQUIPEMENT INFO	**100000**		**91182**				**91182**
Aide données		34852			414		35266
TOTAL SERVICES CLIMATIQUES DONNEES	**50000**	**34852**			**414**		**35266**
TOTAL VALO INITIAL	**250000**	**59328**	**153759**	**1389**	**2714**	**35121**	**252312**
2013-2014							
1/2 yr chargé d'affaires instrumentation	*25710*	*25710*		*2000*			*27710*
Soutien instrumentation Lidar	*110000*					110000	*110000*
Total valo instrumentation		***25710***		***2000***		110000	***137710***
Prolongation 1 mois CDD ESPRI		*2600*					*2600*
Soutien devp services	34280	*34280*		2000			*36280*
Soutien devp services PME	100000					100000	*100000*
Total services climat		***36880***					***138880***

4. Education and Training

4.1 Main objectives and strategy

During the next decade, the needs for education and training on environmental changes should increase largely, because political and economic decisions will have to take global changes into account from global to local scales. This will concern all aspects of our socio-economic system, from citizens to governments, from start-up initiatives to international companies. New opportunities of careers will appear, the skills for existing jobs will be modified by environmental policies and training all along the professional life will become a more critical issue. Teaching on climate has developed since 20 years in close relationship with research activities. It has reached a good maturity, making possible and necessary its spread beyond the research community through projects of reference textbooks, e-learning modules, and collaborative websites. At the same time, the fast expansion of the international dimension of research and education, with a constant motion of students and post-docs between the major laboratories around the world, is also an element to add in the education equation. The various master degrees existing on climate issues in *Ile de France* must improve their coordination and be more visible for French students but also for foreign students.

The objective of L-IPSL, in a very active education and training ecosystem around Paris, is to provide and improve the bridges between the continuously evolving science developed in the research par of L-IPSL, the multi-actor higher-education system (universities, *grandes écoles*, …), and the increasing demand of knowledge about climate issues from various sectors of the society.

4.2 Work Axes

The above general objectives are organized in five axes for the 2013-14 time period, defined and animated by the education committee of L-IPSL, formed by one professor or assistant professor per partner of the L-IPSL:

- ***Axis 1: Improvement of the graduate level education on climate in Ile de France***

A label for master education on climate: In phase with the *plans quinquennaux* of the universities, the education committee propose the development of a Climate path through masters of the L-IPSL partners with a joint knowledge base and skills that all graduate students studying climate should have. A label is proposed validating (1) a minimum knowledge of climate sciences and (2) minimum skills on observing and modelling the climate system. The former will be assessed through identified teaching modules, either specially developed for L-IPSL, or existing in master degrees. The latter will be based on lab/field works organized in the different observing and modelling platform of L-IPSL. This label is an opportunity to progress towards a (necessary) harmonisation of the offer of master degrees on climate sciences in Ile de France and to launch a reflexion to make them more attractive for students in France but also for foreign

French-speaking students worldwide.

An integrated Web platform for information and orientation: A WEB platform is being developed, to present the education offer on climate and environment in *Ile de France*. This platform will inform and guide students towards the best pathways based on their interests and their targeted jobs and skills. It is developed in partnership with PRES UniverSud-Paris and with the support of a contractual assistant hired by L-IPSL to gather and organize information. The originality of the platform is the search engine specifically developed to sort masters depending on keywords chosen by the students and including skills, types of jobs, themes or disciplines to study, for instance. The WEB platform should be released at the end of 2013/ early 2014.

- ***Axis 2 : Promotion of practical training on climate sciences***

Support to lab and field works: Linked with the objectives of axis 1, labex L-IPSL will support the creation and improvement of the offer of lab and field works proposed by licence and master programs on climate and environment in *Ile de France*. This covers lab works (TPs), field work (e.g. students at sea, weeks at *observatoire de Haute Provence*, …) This practical approach to climate sciences is very attractive for students. It also allows training students on classical experimental and modelling techniques (sprectrometry, chromatography, optical methods, programming, data analysis sampling of soils waters and air, …) that can be useful for them whatever is their future professional life. A status of existing lab and field works proposed in the different masters has started.

Support for student projects: Students having a project to realise during their master can benefit of a support from L-IPSL. Projects can imply bibliography search, measurements, modelling or a mixing of the three. Under-graduated students can also benefit of this support if the subject of their project is linked with climate and environment.

- ***Axis 3 : Professional insertion and training***

Development of training modules for professionals: one objective of this task is to develop training modules about climate and environment dedicated to professionals needing minimum knowledge and skills about the different topics treated within L-IPSL. Three modules are in the process to be created: one on air pollution, one on water pollution, and one on climate change and its impacts, linked with the release of the IPCC AR5 in autumn 2013. We also answer to requests from industrials on dedicated training sessions for their employees. We work with the CNRS professional training group to define our program and also with similar services in universities.

Improvement and diversification of professional insertion of graduated students: One aim of this axis is to create closer links between students and their potential employers including academic and non-academic ones. The promotion of our master programs will be organized for services of human resources in private companies, which could potentially hire the graduate students of L-IPSL partners. Their needs will also feed our reflexion to design the offer of formation within L-IPSL in order to better prepare students to future jobs in the climate domain. Contacts have started and will be continued in this direction in 2014.

Axis 4 : Development of e-learning

Finalizing on-going e-learning projects: Developing e-learning content is important both as a complement to presential teaching and as a tool to largely diffuse training programs on climate sciences. Several on going projects have been identified and their finalisation is funded by L-IPSL:

- **An online module on climate system seen from the point of view of observations and data analysis, with a very broad targeted public.**
- **An online module (e-climat : http://broceliande.kerbabel.net/?q=E-Climat) presenting a global view on climate system and on climate change, targeted public being any person with a bachelor in sciences.**
- **The Web site *"le climat en questions"* a series of questions linked to climate and climate change, answered and signed by scientists with different level of complexity depending on the targeted audience (from large public to specialist).**

Pushing for new e-learning projects: L-IPSL also decided to provide leverage funds to start new projects:

- **an online module on the impacts of climate change on marine and continental ecosystems, dedicated to a broad public.**
- **an international master2 on climate change and its environmental, social, political and economical implications. This project (in collaboration with Lille school of journalism, ESJ) aims to provide journalists and communicating people with the scientific notions and the critical skills required to put into perspective climate change in current affairs concerning the society.**

This axis will take benefit of the videoconfering systems funded and installed by L-IPSL in the different sites of the L-IPSL partners.

▪ *Axis 5: Asserting a discipline through the diffusion of teaching and communication material*

After more than 20 years of development, academic teaching about climate sciences has now reached maturity, which needs to be consolidated to play its full role as part of global change education. We propose to initiate a series of reference textbooks, online material, gathering and synthetizing the existing knowledge and skills existing among L-IPSL partners about climate sciences. An editor will be chosen and an e-learning framework chosen to perform these developments, which will be encouraged and supervised by the education committee with the support of a contractual assistant hired by L-IPSL. Thematic schools will be funded and/or proposed and/or advertised to complement existing offer at a national level. This axis has already support to some summer schools and will start to develop its own activities in the second half of 2013.

4.3 Mid and long term objectives

The education committee, with the support of education assistants will:

- **define the label for graduate education on climate sciences**
- **prepare a joint text for *plans quinquennaux* of universities at master level**
- **international networking to develop links with foreign partners for student exchange**
- **define and coordinate the development of a Web site dedicated to all L-IPSL education actions**
- **finalize the Web Site named "le climat en questions"**
- **propose and coordinate the first actions about e-learning.**
- **propose and coordinate the first actions on professional training and insertion**

Training the trainers will allow to largely increase the impact of the transferred knowledge and skills. The L-IPSL education label will give more opportunities to students in their professional life.

The success of these five educational objectives will be assessed through a set of visible deliverables. Within 10 years L-IPSL aims :

- **to improve the national and international visibility of L-IPSL universities and *Grandes Ecoles* with more international students in the masters, renewed and harmonized contents, completed by regular attractive international thematic schools proposed or supported by L-IPSL;**
- **to have a collection of consolidated teaching resources dedicated to a quantitative description of the "Earth system sciences" available in various formats : e-learning modules and full programs, textbooks, web site, training modules for influencers and trainers, … ;**
- **to have closer links and more opportunities in terms of jobs for graduate students, by improving the links with non-academic companies and local authorities.**

4.4 Budget

RECETTES	Colonne1	DEPENSES	Colonne2
NOM	**MONTANT**	**NOM**	**MONTANT**
Subvention L-IPSL	150000	Salaires CDD	53202
		CDD ingénieure pédagogique (Axe 4)	42421
		CDD ingénieure pédagogique (Axe 3)	10781
		Equipement	77869
		Réseau Ethernet (Axe 1 & 4)	27000
		Vidéoconférence (Axe 1 & 4)	49959
		Fonctionnement/Actions	34385
		Missions ESJ (Axe 3 & 4)	2011
		Soutien IPICS (Axe 5)	1500
		Soutien formation LMDZ (Axe 1 & 2)	1700
		Site WEB le climat en questions (Axe 1)	24425
		Soutien université à la mer (Axe 5)	4749
TOTAL	150000	TOTAL	164073
Différentiel	14073		

Appendix A : L-IPSL LABEX initial programs report

Research Actions

June 2013

In the initial phase (2011 – early 2013), the LABEX research program focused on actions that could both be developed rapidly and satisfy the objectives of the LABEX. Three types of actions were proposed, on the basis of responses to internal calls. These actions are summarized below.

- Invitations of foreign scientists to L-IPSL laboratories for a short period of time (0-6 months: seven scientists were invited, gave seminars and participated to the definition of new projects with several laboratories of L-IPSL. The main actions are reported in the following;

- Projects integrating IPSL laboratories with one of the new LABEX partners (IDES and SISYPHE): 2 projects at IDES and 3 projects at SISYPHE, designed to build new or to strengthen previous collaborations with IPSL laboratories were conducted and are reported in the following;

- Projects strengthening or developing infrastructure resources for the development of the LABEX program: the main priorities for common infrastructures in L-IPSL were defined and implemented by TWP1 and TWP2, and are reported in the following.

Visiting scientists program

- ***Pr. Steven Clifford***
- ***Dr. Amato Evan***
- ***Dr. Jerome Fast***
- ***Dr. Hema Hachyutan***
- ***Dr. Andrew Heymsfield***
- ***Dr. Peter Raymond***
- ***Dr. Alessandro Tagliabue***

- **Pr. Steven Clifford – Lunar and Planetary Science Institute (Houston, USA)**

Project Title: modélisation de l'influence du réchauffement climatique sur la stabilité des pergélisols terrestres et planétaires.
Labex sponsor: WP4
Dates: (2 months)

- **DESCRIPTION OF MAJOR SCIENTIFIC ACCOMPLISHMENTS**

Steven CLIFFORD took part in the development of 2 research programs within the Planetary Geomorphology group of IDES (UMR 8148):

1. **Several meetings were done, mostly focused on a new research program about the numerical modeling of the climate warming on the stability of terrestrial and planetary permafrosts. This typically multi-field program implying S. Clifford and three other laboratories partners from the L-IPSL was initiated:**
   - IDES: F Costard (DR.), A Saintenoy (MCF), M Biancheri (MCF), L Dupeyrat (MCF)
   - LSCE: CH Grenier (CR), E Mouche (CR)
   - LATMOS: V Ciarletti (Pr), M Dechambre

Following these meetings, it was decided to focus the research on the effect of the pressure exerted by the interstitial ice during the formation of the permafrost

2. **New interpretations of the MARSIS mission data (MARSEXPRESS, ESA): application to the Northern plain of Mars.**

Besides, the visit also helped to strengthen collaborations on planetary science: The aim of this study is a pluridisciplinary approach dedicated to the interpretation of radar sounding (Marssis data) focus on the northern plains of Mars. That program imply various laboratories labex L-IPSL:(geomorphologist from IDES (F. Costard), physicist (S. Clifford), geophysist (V. Ciarletti, Latmos). During his stay at Orsay, S. Clifford, together with Mouna PettitJean (M1 student at IDES) and F. Costard carried out a GIS showing the correlations between the fluidized ejecta craters, the supposed limit of paleo-shorelines and the permittivity values of the Martian ground ice.

- **SEMINARS**

  - **The martian cryosphere, July 12, 2012, IDES**
  - **The Climatic and Hydrologic Evolution of Water on Mars, Nov 14, 2012 at LSCE.**

- **PUBLICATIONS**

Clifford S. F. Costard and M Petitjean, V. Ciarletti, Mouginot J. and Parker T. Widespread occurrence of volatile rich ground ice in the Northern Plains of Mars. Icarus, in preparation.

- **Dr. Amato Evan – University of Virginia**

Project Title: Development of a theory for land-ocean-atmosphere coupling on decadal time scales
Labex sponsor: WP3
Dates: June 1, 2012 – May 31, 2013

- **DESCRIPTION OF MAJOR SCIENTIFIC ACCOMPLISHMENTS**

Summertime precipitation over the Sahel region of West Africa varies on a multitude of time scales, from synoptic variations in the intensity and location of the rainfall, to the decadal sea-saw of drought and "wet" periods. On long time scales it has long been thought that changes in the meridional gradient of tropical ocean temperature forced changes in the intensity of the monsoon by altering regional surface pressure gradients. But on intraseasonal time scales recent work has demonstrated that monsoon precipitation is instead highly sensitive to changes in the temperature of the Saharan Heat Low; a region of the Sahara Desert exhibiting the highest surface temperatures of West Africa.

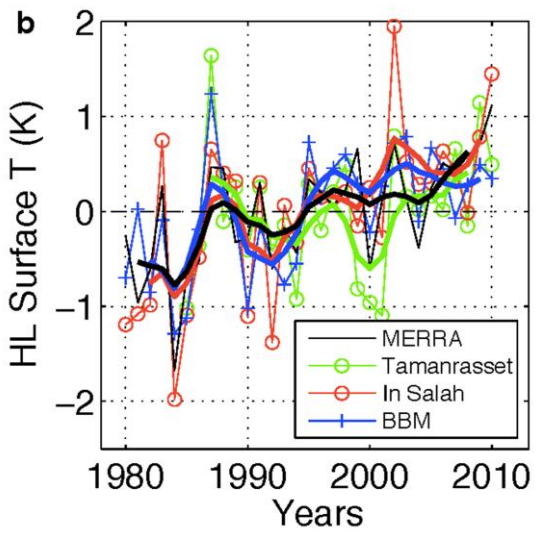


Figure 1. Time series of SHL surface temperature. Plotted are mean summertime surface temperatures averaged over the Saharan heat low from reanalysis and observations at Tamanrasset, In Salah, and BBM, Algeria. Much of the research visit was dedicated to understanding the source and

The major research result stemming from this visit was to reconcile this disconnect between the distinct factors thought to be controlling Sahelian precipitation by developing a theory for monsoon variability that is consistent at all time scales. We determined that, via the greenhouse effect, small changes in water vapor in the atmosphere over the Sahara Desert alter the thermodynamic structure of the Saharan Heat Low, thereby modifying the monsoon circulation and precipitation across the Sahel. Interestingly, we also found that as the temperature over the heat-low region rises, the resultant effect on the regional circulation is to advect *more* moisture into the Sahara, thus further warming the Sahara. We established that a "Saharan-Water vapor-Advection-Temperature" (SWAT) feedback is the fundamental mechanism controlling precipitation across the Sahel on long time scales, the dynamics of which is consistent with the synoptic-scale meteorology of the monsoon. We concluded that the role of the ocean and meridional gradients in tropical sea surface temperatures is to modify the flux of moisture delivered from the tropical Atlantic into the Sahara, thereby setting in motion the feedback described above, and explaining the observed correlation between ocean temperature and monsoon rainfall.

- **TEAMS INTERACTED WITH AT IPSL AND ELSEWHERE**
  - **C. Flamant (LATMOS), S. Janicot (LOCEAN), F. Hourdin (LMD), B. Marticorena (LISA), A. Saci (ONM Algérie), Remi Losno (LISA)**

- **SEMINARS**
  - **Water vapour and the Heat Low: A new theory for interannual-decadal scale variability of Sahel rainfall. *Observations et modélisation de l'humidité au Sahara*, Febuary 2013, Jussieu.**
  - **Water vapour and the Heat Low: A new theory for interannual-decadal scale variability of Sahel rainfall. January 2013, Jussieu.**

- **PUBLICATIONS**
  - **Evan, A. T., C. Flamant, Lavaysse, C, Kocha, A. Saci, 2013: Water vapor over the Sahara Desert and drought in the Sahel. *Science*, submitted.**
  - **Evan, A. T., C. Flamant, 2013: Land-ocean-atmosphere feedbacks in an idealized model the West Africa monsoon. *J. Climate*, in progress.**
  - **Evan, A. T., L. Dehan, C. Flamant, 2013: The SWAT feedback in a high resolution model of West Africa. *J. Climate*, in progress.**

- **CONFERENCE PROCEEDINGS**
  - **Evan, A., C. Flamant, C. Lavaysse, C. Kocha, 2013: Water vapour in the Sarahan Heat Low: A new theory of interannual to decadal scale variability in the summertime circulation over West Africa. EGU General Assembly Conference Abstracts 15, 12262 .**
  - **Evan, A., 2013: On the coupled response of the equatorial Atlantic to West African dust outbreaks. EGU General Assembly Conference Abstracts 15, 12337.**

- **FOLLOW UP ACTIONS**

In addition to publishing new results, the following activities are planned in order to continue to develop and test this new theory of monsoon variability on long time scales.

1. **Conduct high-resolution, idealized, numerical experiments over West Africa that are designed to test the SWAT hypothesis. These numerical computationally expensive model runs are being conducted at the Scripps Institution of Oceanography, with initial results expected in five weeks.**
2. **Perform low-resolution experiments in a global model of the atmosphere and ocean also designed to test the SWAT hypothesis. These experiments will run over a longer time span, roughly 30-years, and will include ocean coupling. Collaborators at the University of Wisconsin have performed several of these model runs and initial results are expected shortly. We are hoping to conduct similar model experiments with the IPSL GCM.**
3. **Prepare and submit a proposal for the NSF to further study water vapor over the Sahara desert. This work will focus on the synoptic-scale response to changes in water vapor over the heat low and will include funding for new instrumentation to be deployed in Algeria, in collaboration with ONM.**

- **Dr. Jerome Fast – Pacific Northwest National Laboratory, USA**

Project Title: Regional scale modeling of trace gases and aerosols in the Arctic
Labex sponsor: WP3-TWP2
Dates: January 8, 2013 – March 7, 2013

- **DESCRIPTION OF SCIENTIFIC ACCOMPLISHMENTS**

One focus of the research visit was on the role of local pollutant emissions in the Arctic. Jerome Fast attended a data workshop associated with the EU ACCESS (Arctic Climate Change, Economy and Society) project (see http://www.access-eu.org/) on air pollution impacts in the Arctic, in Germany (January 21-22, 2013) to become more acquainted with the 2012 (DLR) aircraft campaign when measurements were collected in ship plumes and around oil/gas platforms off the coast of northern Norway. One important modeling issue is being able to simulate the marine boundary layer accurately, since this will greatly influence dispersion of plumes of black carbon and other emissions from ships and oil platforms. Alternative boundary layer parameterizations were tested in the WRF model to see if one performed better than another and was able to show that the Asymmetric Convective Model (ACM) scheme produced more realistic spatial variations in the marine boundary layer. Following discussions with Dr. Jon Pleim (US EPA), the developer of ACM, the code was modified so that it could be coupled with chemistry in the model and be more useful for this type of study looking at transport and dispersion of pollutant plumes in the Arctic boundary layer.

Another focus of the visit was on the importance of gas flaring emissions that have usually been neglected by most modeling studies. This was motivated by recent results (Stohl et al., ACPD, 2013) showing that as much as 40-50% of surface black carbon (BC) in the Arctic could come from this source as well as from seasonal variations (winter max.) in domestic heating emissions. A series of quasi-hemispheric WRF-Chem simulations were performed to investigate the role of flaring emissions on BC concentrations in the Arctic. Test simulations were performed for March and April 2008 when several research aircraft were deployed in the Arctic as part of IPY-POLARCAT that collected BC data. Simulations with two anthropogenic emissions inventories (from the EU ECLIPSE project and POLMIP (POLARCAT Model Inter-comparison Project) were used which have different distributions and magnitudes of flaring emissions, particularly at high northern latitudes over, for example, Russia. An example of the preliminary results is shown below in Figure 1.

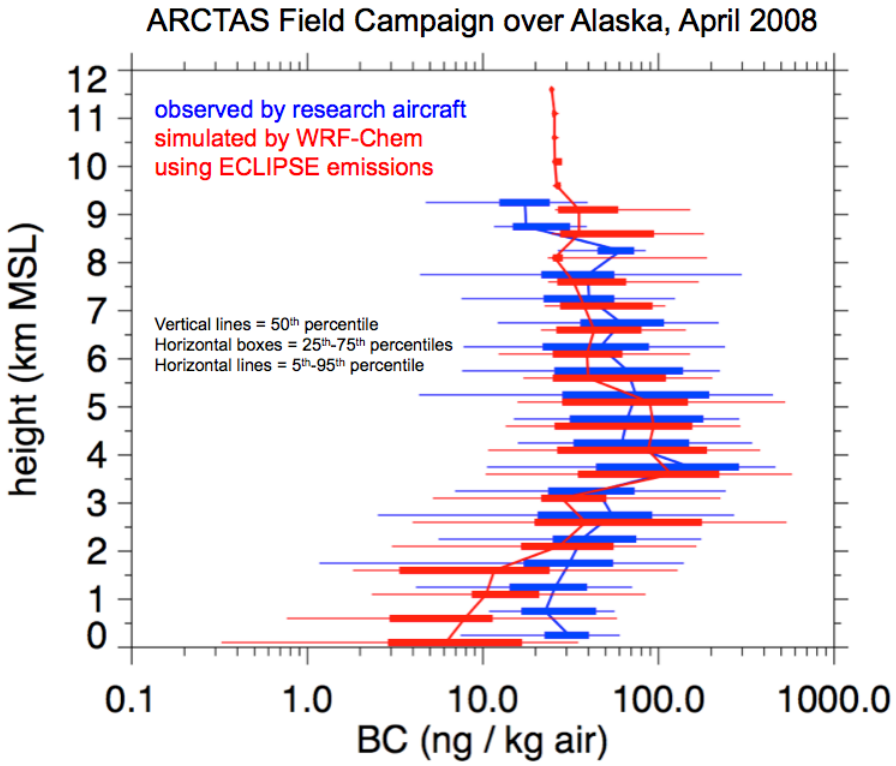


Figure 1 : Comparison between preliminary results from the WRF-Chem model (red) and NASA DC-8 aircraft black carbon observations collected in April 2008 over the Arctic. Data courtesy of NASA DC-8 (Y. Kondo/ M. Koike, U. Tokyo).

- **TEAMS INTERACTED WITH AT IPSL AND ELSEWHERE**

Jerome Fast (PNNL) mostly worked with scientists in LATMOS (Kathy Law, Jean-Christophe Raut, Gerard Ancellet etc.). He also discussed with students and postdocs on modeling issues associated with the use of the Weather Research and Forecasting (WRF-Chem) model and gave several informal WRF-chem tutorials describing details of the assumptions behind the model, including the use of the model for studies of aerosol-cloud interactions. He also interacted with scientists in LMD and became more familiar with on-going research capabilities and activities in IPSL.

- **SEMINARS**

  - ***"Evaluation of WRF-Chem Simulations of Carbonaceous and Inorganic Aerosols over California using Measurements from the 2010 CARES and CalNex Field Campaigns"* at LATMOS, Jussieu (Labex-IPSL seminar)**
  - ***"Downscaling Climate Model Predictions using Consistent Physics between the CAM5 and WRF Models"* at LMD, Ecole Polytechnique (joint IPSL Labex-Regional Climate modeling Pole seminar)**

These seminars described recent research activities associated with modeling aerosols, clouds, and their interactions using the WRF-Chem model. Discussions with members of the Pole took place after

the seminar about downscaling issues.

- **CONFERENCE PROCEEDINGS**
  - ***Fast, J.D., K.S. Law, J. Thomas, B. Quennehen, J.-C. Raut, Z. Klimont, P.-L Ma, B. Singh, P.J. Rasch, Quasi-Hemispheric Simulations of Black Carbon Transport to the Arctic using the CAM5 Physics in WRF, 14th Annual WRF Users' Workshop, 24–28 June 2013, Boulder, USA.***

- **PUBLICATIONS**
  - **At least one paper on these results is anticipated.**

- **FOLLOWUP ACTIONS**

This research collaboration is ongoing in terms of further joint analysis of the model runs. Several sensitivity runs are also being performed to look at the sensitivity of results to different emission datasets and the impacts of wet scavenging. Preliminary results from this work will be presented at the upcoming 14th Annual WRF User's Workshop in Boulder (US) (24-28 June 2013) as well as at the AMAP expert group meeting in Potsdam (26-28 June, 2013).

- **Dr. Hema Hachyutan – Anna University, Chennai, India**

Project Title: Joint collaboration for the study of Indian Monsoon
Labex sponsor: WP5
Dates: December, 8 – December 30, 2012

- **DESCRIPTION OF SCIENTIFIC OBJECTIVES**

The Indian subcontinent and the adjacent seas are the location of a strong monsoon system, which has a profound impact on the socio-economy of one of the most densely populated areas of the world. Climate modeling and forecasting are notoriously difficult because the Indian Monsoon is a particularly complex system, potentially affected by a large array of periodic to semi-periodic forcings, regional to global in extent, with timescales ranging from interanual changes (e.g. El Niño-Southern Oscillation-ENSO) to 10^4-10^5yr orbital modulation of solar insolation. The LSCE, LOCEAN and IDES have launched several collaborative programs, which aim to understand Indian monsoon long-term evolution and millennial-scale variability trough continental and marine records, and the completion of model/data comparisons (ANR ELPASO, ANR MONOPOL).

Our collection of climatic archives does not allow, however, to properly address the Indian monsoon paleo-variability at decennial to centennial time scales, over the last millennia. In order to (i) improve our understanding of paleoclimatic proxies over the Indian subcontinent, and (ii) collect high quality paleoclimatic records covering the late Holocene, the WP5 invited Dr Hema Achyuthan, Head of the Geology department at Anna University (Chennai, India), and a well-known specialist of continental Indian paleo-environments, with the goal to set up a long-term Indo-French collaboration around monsoon variability. During this seminal, 3-week visit, L-IPSL scientists interacted with Dr Achyuthan on five main topics: (1) the evolution of the Thar desert and the selection of well-dated proxies that could be used for model/data comparison; (2) the prospect of collecting new samples for dendrochronologic studies in the Kerala and Tamil Nadu areas; (3) the organization of a future expedition for collecting new speleothem series; (4) the selection of coring sites within extremely high sedimentation rate areas of the Indian margin and the organization of a joint Indo-French scientific cruise on board the french R/V Marion *Dufresne*; and (5) the sampling of a well-developed Toba ash layer.

- **L-IPSL SCIENTISTS WHO INTERACTED WITH Dr HEMA HACHYUTAN**

F. Bassinot, D. Blamart, P. Braconnot, C. Colin, V. Daux, D. Genty, H. Guillou, M. Kageyama, C. Kissel, A.M. Lezine, V. Masson-Delmotte, S. Nomade, S. Sepulcre, B. Turcq.

- **SEMINARS**

  - **Late Quaternary environments of the Thar desert, Rajasthan, LSCE-Orme.**
  - **The Young Toba ash layer and its impacts ~ 74 ka ago, LSCE-Vallée.**

- **FOLLOW UP ACTIONS**

The objectives and the practical aspects of this new Indo-French collaboration – including exchanges of students - will be formalized through a MOU jointly prepared by Dr Achyutan, for the Indian party, and by Dr Franck Bassinot, head of WP5.

- **Dr. Andrew Heymsfield – National Center for Atmospheric Research**

Project Title: Better understanding of cloud processes and improving remote sensing cloud retrieval methods in Tropics
Work Package: WP1
Dates: May 14, – June 23, 2012

- **DESCRIPTION OF SCIENTIFIC OBJECTIVES**

The aim of this collaborative work was to better understand the mechanisms involved in rain production in convective cloud system in the Tropics and help to improve their representation in GCM. During the last two Megha-Tropiques preparation/validation campaigns, over West Africa and the Maldives, we collected a large amount of airborne radar (RASTA) and in-situ measurements that we want to compare to those collected during previous campaigns in tropical area such as TC4 (Costa Rica), NAMMA (Cape Verde, AF), GRIP (Hurricanes, western Atlantic), and the most recent campaign, ICE-T (St. Croix, VI). The Particle Size Distributions, Fall speeds, Radar Reflectivity (94 GHZ) and ice water contents, were parameterised as a function of temperature and used for the development of retrieval algorithms and model parameterisations.
This work also helped to improve our satellite radar, lidar and IR forward models for the current CloudSat/CALIPSO mission and the future EarthCare mission. Dr Andrew Heymsfield is one of the most famous specialists in cloud microphysics and its expertise is crucial. Our guest has been working with Dr Julien Delanoë and Dr Jacques Pelon at LATMOS for more than 1 month (May, June 2012), with Dr Julien Delanoë for the cloud microphysical processes and algorithm improvements and with Jacques Pelon on the validation of IIR products. These algorithms are and will be used to build cloud properties climatologies and help to evaluate GCM (Delanoë et al. 2011).
This collaborative has also reinforced our interactions with the mesoscale group at NCAR. The work done on the normalized particle distribution will be submitted by the end of June 2013 (Delanoë, J., A. J. Heymsfield, A. Protat, A. Bansemer and R. J. Hogan : Normalized Particle Size Distribution for remote sensing application, JGR). The outcome of this work is illustrated in Figure 1 below. Note that the CloudSat-CALIPSO ice cloud product developed by Dr Delanoë has been used to evaluate ice clouds in NCAR GCM model (recently submitted: Improved cirrus simulations in a GCM using CARMA sectional microphysics by Charles Bardeen et al.).

- **COLLABORATIONS**

  - **Validation of CALIPSO/IIR products using *in situ* ice-cloud microphysics observations acquire during the TC4 field campaign (J. Pelon, LATMOS),**
  - **Size distribution of ice particles between -85°C à 0°C (J. Delanoë, LATMOS),**
  - **Improvement of the microphysics model in the DARDAR-CLOUD algorithm and evaluation of the relationship between extinction and ice content (J. Delanoë, LATMOS),**
  - **Improvement of the microphysics model in the RadOnVar algorithm and application to the radar data collected during the airborne field campaigns Megha-Tropiques 1 et 2 (J. Delanoë, LATMOS),**
  - **Cirrus et contrails microphysical properties (V. Noël & H. Chepfer, LMD).**

- **SEMINARS AND VISITS**
  - **Visit to LERMA and discussion with Eric Defer (23 May 2012)**
  - **Seminar "Ice Crystals and Snowfall at the Surface and in the Atmosphere" at LATMOS (24 Mai 2012)**
  - **Visit to LAMP (Clermont Ferrand) and discussion with Alfons Schwarzenboeck (25 May 2012)**
  - **Seminar « Holes in clouds: what they are, how they are produced, and why they may be important » at LMD (7 June 2012)**
  - **Seminar "Holes in clouds: what they are, how they are produced, and why they may be important" at LATMOS (14 June 2012)**

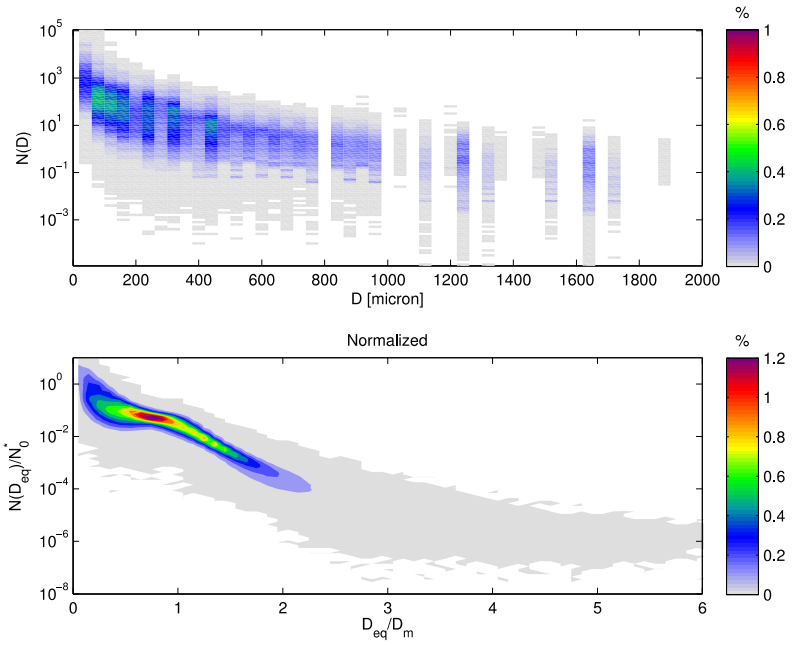


Figure 1 : Impact of the normalization technique on ice cloud size distribution. The size distribution before (after) the normalization is shown in the top (bottom) panel. The dataset corresponds to measurements acquired during 8 airborne field campaigns in different parts of the globe (Polar Regions, mid-latitudes, tropics) with temperatures ranging from -80°C à 0°C. This dataset is invaluable.

- **PUBLICATION**
  - **Delanoë, J., A. J. Heymsfield, A. Protat, A. Bansemer and R. J. Hogan : Normalized Particle Size Distribution for remote sensing application. To be submitted to JGR.**

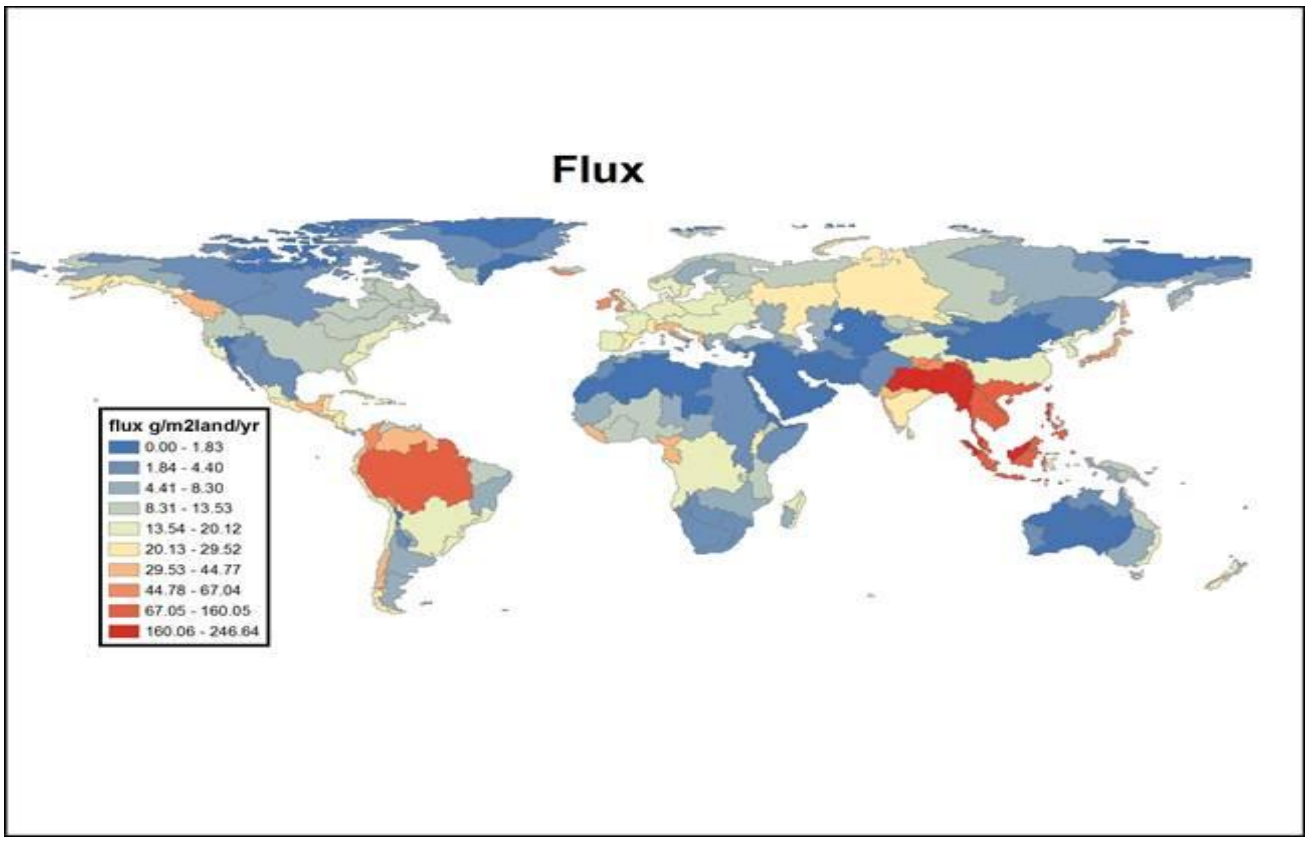
- **Dr. Peter Raymond – Yale School of Forestry and Environmental Studies**

Project Title: First assessment of regional CO2 fluxes outgassed by river
Work Package: WP1
Dates: Feb 1 – Mar 15, 2013 (a follow-up 2-week mission was also funded)

- **DESCRIPTION OF MAJOR SCIENTIFIC ACCOMPLISHMENTS**

The major research result obtained during the short visit was the execution of a global analysis of the CO2 fluxes outgassed by rivers of the globe, using pCO2 data, gas exchange formulations function of stream order and climate data to estimate stream areas. The new CO2 flux outgassed by rivers is 2-3 times larger than previous estimate.

Inland waters are increasingly seen as active components of the global carbon cycle The transfer of carbon dioxide from inland waters to the atmosphere has been demonstrated to be a significant pathway within regional carbon cycles However, global estimates of this transfer have been hampered by a lack of a framework for estimating the surface area and gas transfer velocity of inland waters and the absence of a global CO_2 database. Although regional fluxes as high as 0.6 Pg C yr^{-1} have been reported for components of inland waters of the Amazon {Richey, 2002 #110;Johnson, 2008 #184} and 0.5 Pg C yr^{-1} for the streams and rivers of temperate regions of the northern hemisphere global estimates place the efflux at only ~1 Pg C yr^{-1}.Here we report, for the first time, the regional variation in global inland water surface area, dissolved CO_2 concentration and gas transfer velocity at the scale of large regions (COSCAT). We report a global stream and river CO_2 evasion rate of 2.2 Pg C yr^{-1} with a range of 1.8-2.6. In addition, we obtain a lake and reservoir evasion rate of 0.32 with a range of 0.060-0.84 (5^{th} and 95^{th} confidence intervals), in line with previous estimates. The resulting global evasion rate of 2.6 Pg C yr^{-1} is considerably higher than previous estimates, due to the larger evasion rate of streams and rivers. This analysis also predicts global hot spots in this stream and river evasion with ~70% of the flux occurring over just 20% of the land surface of the globe. The source of inland water CO_2 is still not known with certainty and new studies are needed to research the mechanisms controlling CO_2 evasion globally.



- **TEAMS INTERACTED WITH AT IPSL AND ELSEWHERE**
  - **P. Cias, C. Rabouille (LSCE), J. Garnier, M. Meybeck (SISYPHE), J Polcher, M. Guimberteau, A. Ducharne (LMD), P. Régnier, R. Lauerwald (ULB).**

- **SEMINARS**
  - **One seminar given at Sisyphe (Feb 22)**

- **PUBLICATIONS**
  - **Raymond et al. Hotspots for global stream CO_2 evasion. Nature, in revisions**
  - **Regnier et al. Anthropogenic perturbation of the land to ocean carbon flux. Nature geosciences, in press, 2013**

- **FOLLOWUP ACTIONS**

In addition to publishing new results, the following activities are planned in order to continue to develop and test this new theory of monsoon variability on long time scales.

1. **Hire a postdoc for 2 years (R. Lauerwald) who will work at IPSL with the above mentioned IPSL teams, P. Regnier, and P; Raymond for incorporating river C transport and CO2**

outgassing in the ORCHIDEE land surface model (Labex WP1 action)

2. **Work on spatially explicit data-driven models to calculate the distribution of CO_2 outgassing by rivers**
3. **Prepare and submit a proposal to the BELPO (Belgian basic science organization) to develop a full scale integration of the river C Cycle**

- **Dr. Alessandro Tagliabue – CSIR, Cape Town, South Africa (now lecturer at the University of Liverpool, UK)**

Project Title: First assessment of regional CO2 fluxes outgassed by river
Work Package: WP4
Dates: April 4 – May 31, 2012

- **DESCRIPTION OF MAJOR SCIENTIFIC ACCOMPLISHMENTS**

Discuss PISCES model developments : Alessandro Tagliabue is one of the core developpers of the PISCES model, the ocean carbon cycle component of the IPSL Earth System Model. His visit gave the opportunity of gathering all developpers to discuss the top priorities in PISCES upcoming developments. His expertise is mainly on the iron cycle modelling.

Work and discuss specifically on the seasonality of marine productivity in the Southern Ocean : Several conflicting theories have been proposed to explain the onset of the phytoplankton bloom in the SO. The scientific project supporting Alessandro's visit was aiming at using the PISCES model to test these different theories. To do so, Alessandro worked with J. Llort (phd student at LOCEAN/ Marina Lévy) to implement a 1-D configuration of the PISCES model. Work is still in progress. A manuscript is in preparation (LLort, Lévy, Tagliabue et al., in preparation), another has been submitted to Nature Geosciences (Tagliabue et al. NG submitted).

- **SEMINARS**

  - **A. Tagliabue, "Iron in the Southern Ocean", invited talk at the LEFFE/TANGGO meeting organized in Grenoble (22-23 May 2012)**

- **WORK WITH STUDENTS**

  - **Jorge Martinez-Rey (Modelling the oceanic N_2O cycle), phd student w/ Laurent Bopp, LSCE.**
  - **Joan LLort (Seasonality of phytoplankton blooms in the Southern Ocean), phd student w/ Marina Lévy, LOCEAN.**

- **PUBLICATIONS**

  - **Tagliabue, A., J.-B. Sallee, A. R. Bowie, M. Levy, S. Swart and P. W. Boyd, Towards Reconciling Seasonal Iron Supply and Biological Demand in the Southern Ocean, under review for Nature Geoscience, May 2013.**
  - **Ayata, S.-D., M. Levy, O. Aumont, A. Sciandra, J. Sainte-Marie, A. Tagliabue and O. Bernard (2013), Phytoplankton growth formulation in marine ecosystem models: should we take into account photo-adaptation and variable stochiometry in oligotrophic areas? J. Marine Syst., doi: 10.1016/j.jmarsys.2012.12.010**
  - **Llort, J., M. Levy, A. Tagliabue, S-D Ayata, J.-B. Sallée, J. Le Sommer and L. Bopp et al., Seasonality of phytoplankton blooms in the Southern Ocean, in preparation.**

- **FOLLOW UP ACTIONS**
  - **EU IRSES project SOCCLI (partners including: CSIR, South Africa, and IPSL, France)**
  - **extended visits of M. Levy, C. Ethe, J. LLort and L. Bopp in Cape Town.**

Integrating projects for IDES and SISYPHE

- **IDES Project – PERGELENA : Talik evolution under the Lena river (Siberia): field study, laboratory simulation and numerical modeling**

- **IDES Project : Reconstructing climate dynamics by using geochemistry of sedimentary archives**

- **SISYPHE project - GPR-Ô : design of a ground penetrating radar in the bandwidth [100MHz-600MHz] for the estimation of soils volumetric water content**

- **SISYPHE Project – CHARM : Regional and global atmosphere/hydrology coupling – Strengths and weaknesses of the IPSL earth system model**

- **SISYPHE Project - HydrOracle project : Analysis of regional hydrogeological simulations using ORCHIDEE water fluxes prior to study the impact of both climate and land use changes within the framework of the Oracle ANR project**

- **IDES Project - PERGELENA - Talik evolution under the Lena river (Siberia): field study, laboratory simulation and numerical modeling**

IDES contact : François Costard (CR) and Nicolas Roux (PhD), UMR 8148 *IDES* Université Paris-Sud, Bât. 509. 91405 ORSAY Cedex francois.costard@u-psud.fr
LSCE contact : Christophe Grenier and Emmanuel Mouche, (IPSL-*LSCE*, *UMR 8212 CNRS-CEA-UVSQ, Orme des merisiers, 91191 Gif-sur-Yvette Cedex*, 01 69 08 93 62) christophe.grenier@lsce.ipsl.fr

- **REPORT**

Current climate warming strongly affects the permafrost in the artic regions which are very sensitive to the climatic variations. In Yakoutia, permafrost is particularly developed (max. thickness 1500 m) and continuous. The rivers in central Siberia are characterized by an ice break-up regime in spring. A talik (thawed sediment within the permafrost) is present under the rivers and plays a significant role in the hydrology and thermal regime of the system. However, its role and the parameters controlling its development are largely unknown both for Lena and its tributary.

This research program implies physicists, geologists and geomorphologists in the framework of a close scientific cooperation between IDES and the LSCE. The main goal concerns the development of the interaction between the permafrost, the active layer thickness and the evolution of the talik.

F. Costard and Ch Grenier, respectively from IDES and LSCE laboratories, are the leaders of the program.

With the financial support from L-IPSL, we did a 10 days mission in Yakutia thanks to a close cooperation between IDES and the Permafrost Institute (Yakutsk). We used various data loggers to study the propagation of the thawing line under the river beds. We carried out several field surveys with our Yakutian colleagues for the characterization of the permafrost table and the active layer.

Such a program is quite innovative in the hydrological community and will make it possible to answer questions about the exchanges between aquifer-river in a periglacial environment. We plan to go back to the field in September 2013.

In order to follow the evolution with time of the talik, we plan other drillings near the river (mission at the end of March 2013 and at the end of September 2013). In the same time, we lead several experiments in a cold room at IDES in a hydraulic plume simulating a flow over permafrost. The measures of the propagation of the thawing line will be then compared with the numerical model from LSCE.

- ## IDES Project - Reconstructing climate dynamics by using geochemistry of sedimentary archives

IDES contact : Sophie Sepulcre

- **REPORT**

The aim of this project is to finalize a clean room at the IDES laboratory in order to reconstruct past climate changes by studying sedimentary archives to better constrain natural climate changes of the last millenium (pre-industrial period) as well as older time intervals characterized by abrupt climatic events. Rapid climate changes are especially studied in order to document the mechanisms of these abrupt events and, in particular, to better constrain the processes underlying their occurrence. Our final aim is to understand past climate changes to better apprehend future climate variability. This research is fully integrated in the WP 2 and 5 of the L-IPSL project.

Our approach is especially focused on the use of the geochemical signature of marine sediments as a proxy for paleoenvironmental changes. Indeed, in paleoclimate research, the geochemistry helps to point out, quantify and characterize the processes governing these changes. Our request was to complete a clean room at IDES with specific locations dedicated to the chemical sample pre-treatment before isotopic and elemental analysis, especially on the newly acquired MC-ICP-MS (coupled to a laser ablation) set up at LSCE in 2010 thanks to a collaboration between IDES and the LSCE. The installation of this new clean room will be effective in June 2013 and will help the IDES researchers to get a full independence for sample preparation to achieve our collaborations, especially in the framework of the L-IPSL project.

Paleoclimate work at IDES is especially focused on three specific objectives: i) to reconstruct the ocean circulation dynamics in the North Atlantic, ii) to better understand the processes involved in rapid climate changes, in particular by comparing marine (surface and deep records) and continental (lake, ice) archives and iii) to study the rapid indian and asiatic monsoon variability from decadal to orbital timescales.

In order to answer to these scientific objectives, analysis of radiogenic (Sr, Nd, U-Th-Pb), stable ($\delta^{11}B$) isotopes and minor and trace elemental ratios (Mg/Ca, B/Ca) are determined in different sedimentary archives such as deep-sea corals, planktonic and benthic foraminifera and the detrital sediment fraction. Our research is especially focused on the North Atlantic and Mediterranean areas, the South Pacific, the South China Sea and the Bay of Bengal and is led through several national or international programs (Atlantic, ANR NEWTON; South China Sea, LIA-MONOCL; Bay of Bengal, ANR MONOPOL; South Pacific: LEFE-PACHIDERME and LEFE-CHICO; North Atlantic and Mediterranean areas: ANR HAMOC submitted in 2013, INSU PALEOMEX - COFIMED, LEFE-GéoFoBe) for which strong collaborations exist between IDES, the LSCE and the LOCEAN.

The new clean room installed at IDES strongly contributes to develop our research. Indeed, recent (MONOPOL, Bay of Bengal, May-June 2012; South China Sea, CIRCEA, June 2012; ICE-CTD, North Atlantic, June-July 2012, EuroFLEETS cruise Mediterranean-Atlantic Gateways, June 2013)

oceanographic campaigns have provided appropriate samples for our research. Studies performed in the framework of PhD thesis such as the end signature of deep-water masses and cold water corals in the North Atlantic and the Mediterranean Sea (Quentin Dubois-Dauphin, ANR HAMOC submitted in 2013 and INSU-COFIMED) can now be achieved at IDES. Thanks to Chinese and French collaborations developed in the LIA-MONOCL (IDES-LSCE), analyses of seawater and sediment εNd from the South China Sea are planed at IDES during summer 2013 as part of the PhD thesis of Qiong Wu. Geochemical analysis will also be sonly performed on benthic foraminifera (summer 2013, ANR-MONOPOL and LEFE-GéoFoBe, Sophie Sepulcre and Master 2 course of Naoufel Haddam) and sediments (September 2013, ANR-MONOPOL and PhD grants CSC-P11, Zhaojie Yu) from the Bay of Bengal .

- **SISYPHE project - GPR-Ô : design of a ground penetrating radar in the bandwidth [100MHz-600MHz] for the estimation of soils volumetric water content.**

SISYPHE CONTACT : F. Rejiba, UPMC, UMR 7619, SISYPHE

- **REPORT**

Participants L-IPSL: *S. Flageul, UPMC, UMR 7619, Sisyphe , R. Polycarpe, UPMC, UMR 7619, Sisyphe , A. Saintenoy, UPSUD, UMR 8148 IDES, M. Biancheri-Astier, UPSUD, UMR 8148 IDES, V. Ciarletti, USVQ, UMR 8190 LATMOS*

The aim of this project is to design a wide- band and low-cost GPR transmission link for subsurface geophysical investigations. Basically, GPR is used for 1) the imaging of the electromagnetic reflectivity in order to assess the geometrical structure of the ground, and 2) the estimation of the electromagnetic parameters and specially the effective permittivity. In order to address point 2), a classical approach consists in measuring the complex reflection coefficient (S11) prior its inversion. The inversion result consists of an effective permittivity over the working bandwidth which characterizes the near surface (the volume of investigation has to be estimated).

Another way consists in acquiring continuously a WARR setup (wide Angle Refraction Reflection) using an array of similar antennas: the emission is located in one or the other extremities of the antenna array, and the other antennas are used as receivers. In that case, it is possible, with a "velocity analysis" process, to recover the vertical variations of the apparent velocities which are directly related to the real part of the effective permittivity. Depth of investigation in that case depends both on the electrical conductivity and the length of the antenna array. Comparing to TDR (Time domain reflectometry) measurements, such a GPR setup could be used in mapping mode which allows the users to reach a far better efficiency and productivity than TDR. Nevertheless, as for any geophysical investigations, a calibration procedure must be performed at regular positions (for example oven drying checks for the volumetric water content interpreted).

The current GPR_Ô funding has been entirely dedicated to the purchase of a 4-channels 1GHz oscilloscope in order to design the impulse generator as well its testing when coupled with antennas.

The scientific approach is based on three steps:

1. **Numerical modeling using a full wave 3D FDTD (Finite Difference Time Domain) solver of the entire transmission link including the antenna and the ground, in order to design the optimal antenna geometry.**
2. **Design of the impulse generator and the antennas which allow the delivery of a wideband and energetic impulse which spectrum cover at best a range between 100MHz and 1GHz. Currently, an ellipsoidal antenna shape has been retained (Fig. 1). The overall system mounted on a CART with an odometer is a work in progress and is a crucial step to**

compare accurately the results with radargrams obtained with any commercial system.

3. **The physical interpretation of the complex reflection coefficient or the WARR radargram section, to determine, first the complex effective permittivity (including the polarization energy loss and storage, as well as the conduction part) and second, the choice of the mixing law that relate the effective permittivity to petrophysical and hydric parameters (water content, degree of saturation, argilosity).**

- **PRELIMINARY RESULTS AND SHORT TERM PLANNING (~6 MONTHS)**

FDTD simulations then experimentations confirm that a simple ellipsoid antenna geometry (dipole) allows a reflection coefficient bellow -10dB over a significant bandwidth. Fig. 2 illustrates the S11 response for several couple (real permittivity, conductivity) over a half space. This sensitivity analysis is the first step to assess if the inverse problem is well posed.

A first prototype of a bistatic GPR transmission link is ready to use in point by point mode (Fig. 1). In addition to the rigid and shielded ellipsoid antennas, a flexible model with a neoprene support is also tested to assess the gain in term of impedance adaptation between antennas and the ground natural rugosity. The CART including the odometer that will host electronics parts and the antennas is not ready. Furthermore, more channels are required in order to perform accurately a WARR acquisition as well as AVO (Amplitude Versus Offset) analysis. The finalization of the prototype including all in situ tests requires additional funding that are currently obtained through other programs.

In situ test are planned, and should be first performed over an already well identified anomalies as empty pipes (Fig. 3) with a commercial GPR (here a Pulse Ekko PRO - Sensors and software). The main objective at this level is to evaluate: 1) the received power comparing to the RRE (Radar Range Equation), 2) the efficiency of the shielded antennas, and 3) the mechanical reliability of the device.

Mapping of the water content in an agricultural context should be done in the Orgeval basin (77) which is a part of the GIS (group of scientific interest) ORACLE.

There are currently no international publications directly related with the current developments, in order to preserve the possibility of patenting. This may change in accordance with the partners, based on the patent potential.

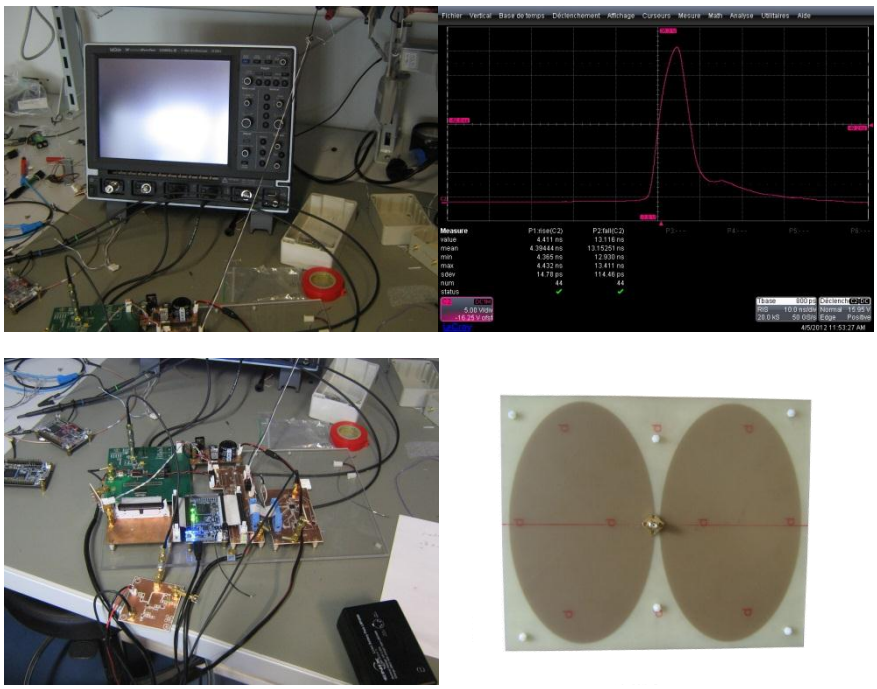


Figure 1 : (UL) 4 Channels Oscilloscope 1Ghz. (UR) gaussian source 5ns (FWHM. (LL) impulse generator prototype. (LR) ellipsoïd antenna dipole.

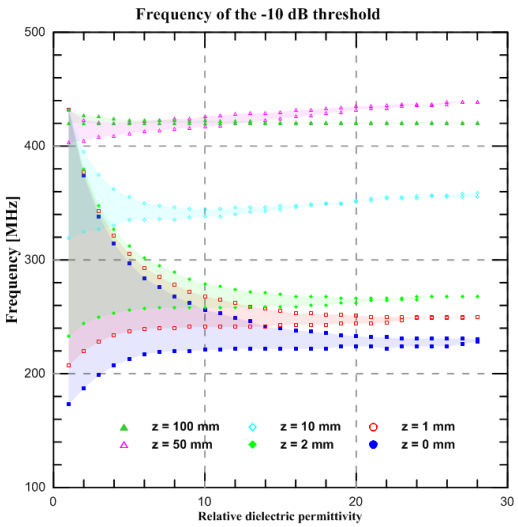


Figure 2 : Envelope of the minimum S11 frequency mark corresponding to the -10dB threshold. Antennas are situated at several heights (z) over a half space (σ,ε). The upper limit corresponds to a conductivity σ=0, for the lower limit σ=100mS/m.

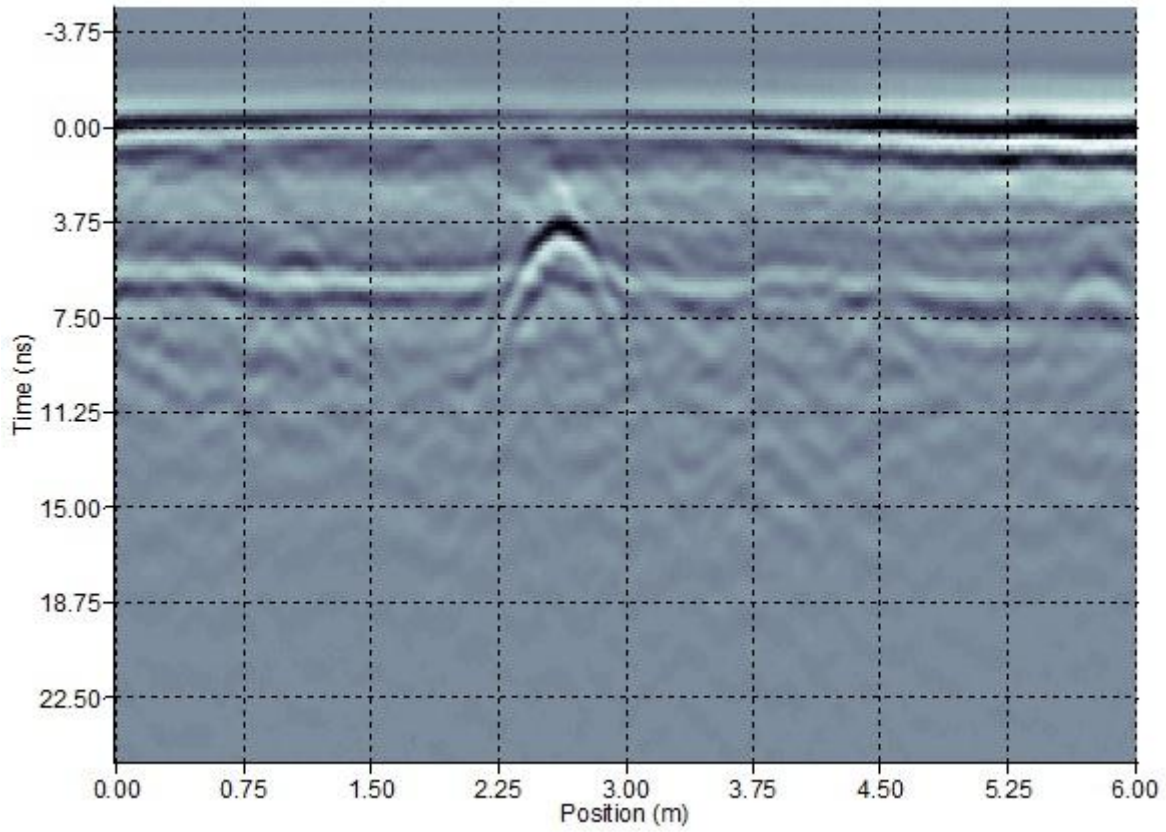


Figure 3 : Radargram obtained with a PE PRO (S&S) at 500MHz nominal frequency, over a concrete pipe (i.e. strong diffraction hyperbola at 2.5m distance), buried beneath an asphalt pavement.

- ## SISYPHE Project – CHARM : Regional and global atmosphere/hydrology coupling – Strengths and weaknesses of the IPSL earth system model

SISYPHE CONTACT : A. Ducharne
LMD contact: F. Cheruy

- **REPORT**

1. Overview

This project stems from a close collaboration between Sisyphe and LMD, which aims at improving the representation of the coupling between continental surfaces and atmosphere. This benefits from ongoing developments regarding :

- the ORCHIDEE land surface model, with the implementation of a physically-based description of the soil water fluxes using the Richard equations (ORC-11) instead of the conceptual description of soil hydrology (ORC-2) implemented in the IPSL-CM up to now ;
- the LMDZ GCM, with a complete reworking of the boundary layer/convection/clouds parameterizations. This new package, called NP and used in simulations IPSL-CM5B, is compared to the standard package NP, used in IPSL-CM5A.

The collaboration started with the PhD thesis of Aurélien Campoy, with two publications in which LMDZ was used in zoomed and nudged mode (Chéruy et al., 2013 ; Campoy et al., 2013).

The specific goals of the CHARM project are to assess the effects of the new soil hydrology and new atmospheric package on climate simulations in the « normal » mode (regular grid and no nudging) used in CMIP5 simulations. The actions supported by the CHARM project, and summarized below, are:

- a comparison of the impact of the standard and new atmospheric packages on large-scale droughts in historical simulations over Europe (Master-2 training of Corentin Lemaire, 2012)
- the preliminary analysis of the influence of ORC11 on historical and future climate simulated by the IPSL model (funding of the last 5 months of the PhD of Aurélien Campoy, which will be defended in June 21st, 2013)
- a joint analysis of land-atmosphere coupling in various CMIP5 simulations prepared for the next IPCC report

2. Impact of the standard and new atmospheric packages on large-scale droughts in historical simulations over Europe

This work started with a critical review of several indices proposed in the literature for the evaluation of drought occurence, duration, and intensity. As the concept of ORC-2, used for CMIP5 simulations, renders meaningless the use of diagnostics based on root zone soil moisture to evaluate the impact of the atmospheric physics, the efforts concentrated on the precipitation characteristics which drive meteorological droughts. Significantly different number of precipitating days, precipitation intensity, and duration of the precipitating events, have been diagnosed in the SP and the NP historical CMIP5

simulations, with NP physics tending to have less raining days, less intense, and shorter rainy events. The differences are especially marked over Central Europe. The analysis revealed that the NP scheme produces puzzling seasonal cycle of the precipitation, with a strong under-estimation in summer with respect to satellite observations. Possible explanations concern the convective scheme, in particular its closure and the interaction with the boundary layer scheme, and the large scale dynamics. They are currently evaluated by the LMD model developers.

3. Sensitivity of climate to the new soil hydrology scheme

We performed sensitivity climate simulations with forced SST derived from observations (AMIP) or from coupled CMIP5 master experiments. In summer, over mid-latitudes continental areas, ORC-11 increases evapotranspiration, especially in zones where near surface temperature tends to be over-estimated. Scaling the mean temperature bias with the mean regional values of the evapotranspiration for all AMIP simulations available in the CMIP5 database shows that the lower the summertime evapotranspiration is, the higher the temperature bias (Fig. 1). Highly biased models also display a too modest radiative effect of clouds at the surface. At IPSL, the use of the NP package improves slightly on this later deficiency without cancelling it. Further developments are still required. Besides the particular results for the IPSL-CM model, this study underlines that the atmospheric and land-surface schemes, but also the way their coupling plays in the climate models, are at the heart of some biases present in models used for the climate projections.

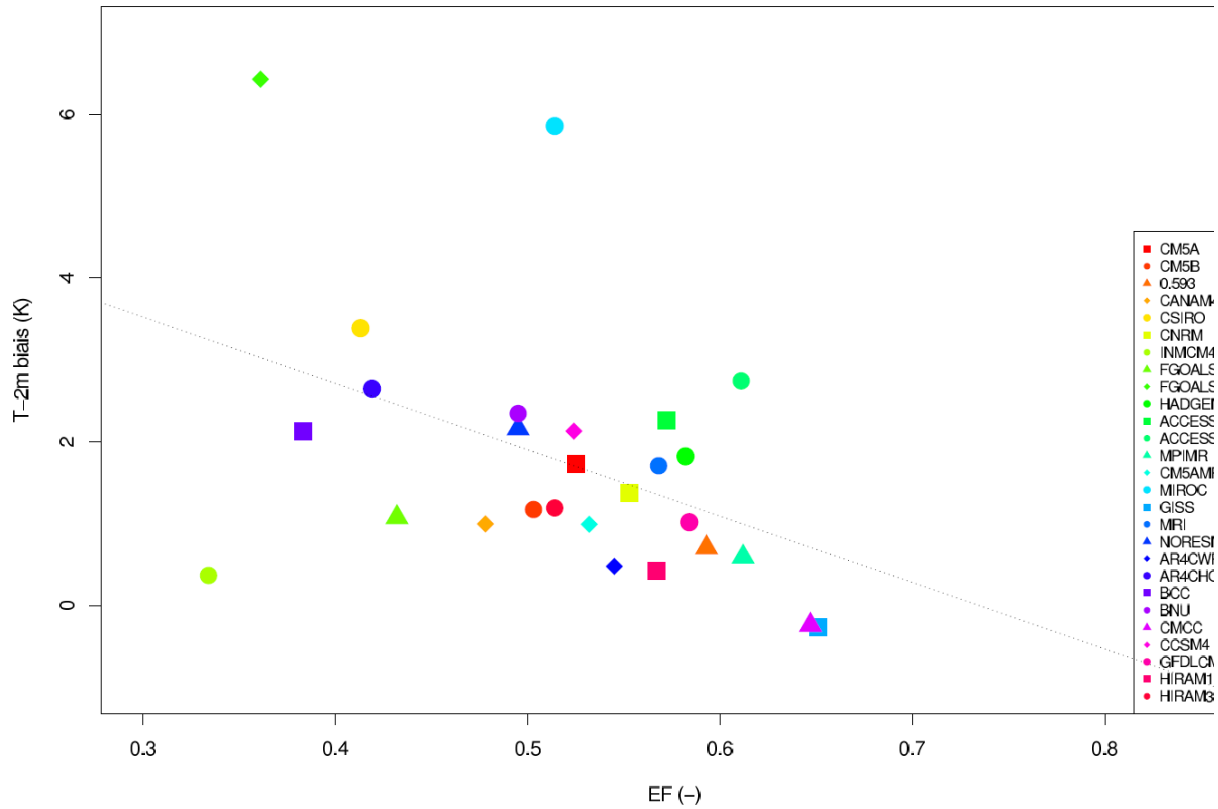


Figure 1 : T-2m bias in the AMIP-CMIP5 simulations with respect to the CRU observations, as a function of the evaporative fraction, over Europe, in summer.

The end of Aurélien Campoy's PhD was devoted to preliminary analyses regarding the role of the soil hydrology scheme in the IPSL climate projections. We compared several idealized 2xCO_2 experiments, with the standard physics and a 96x95x39 discretization. Each experiment consists of two 30-year « climatological » simulations, both with the vegetation map and aerosols from year 1998, but with different CO_2 concentrations and SSTs (Table 1). This set-up was elaborated in collaboration with Frédéric Hourdin and Jean-Louis Dufresne. The various experiments differ by their soil hydrology scheme: C2 (ORC2 with a 2m-soil), C4 (ORC2 with a 4m soil, as in CMIP5 simulations), C11 (ORC11 with a 2m soil). On average over the continents, in both past and future climate, we find a clear increase in evaporation from C2 to C4 to C11, which induces a precipitation increase (evaporation recycling) and a cooling of the lower atmospheric levels (Table 2). A classification in 6 climatic zones has been performed for a finer analysis. This confirms the sensitivity of the simulated CLIMATE to the soil hydrology schemes, but it did not allow us to demonstrate a coherent impact of the soil hydrology scheme on the climate sensitivity, even in the « temperate humid » zone where the warm bias of the CMIP5 models seem related to the evaporative fraction.

	REF98	2xCO2
CO_2 concentrations	365 ppm	730 ppm
SSTs	Interannual mean of 1988-2007 AMIP maps	Interannual mean of 1988-2007 AMIP maps + SST anomaly after 70 years of +1 %CO_2/yr, leading to double CO_2 concentration

Table 1 : Differences between the reference and 2xCO2 simulations.

	REF98			2xCO2		
	C2	C4	C11	C2	C4	C11
Evaporation (mm/d)	1,27	1,37	1,54	1,17	1,27	1,47
Precipitation (mm/d)	2,19	2,28	2,44	2,17	2,25	2,42
Runoff (mm/d)	0,92	0,93	0,90	0,98	1,00	0,95
Air temperature (°C)	14,02	13,98	13,14	16,98	17	16,07
ΔTa (°C)				*+2,96*	*+3,02*	*+2,96*
ΔP (mm/d)				*+0,02*	*-0,03*	*-0,02*

Table 2 : Main differences between the performed experiments, on average over all the continents (excluding Antartica and Greenland), and over the 30 years of simulation.

- **RELATED PUBLICATIONS AND COMMUNICATIONS**

  - **Campoy A, Ducharne A, Chéruy F, Hourdin F, Polcher J, Dupont JC (2013). Response of land surface fluxes and precipitation to different soil bottom hydrological conditions in a general circulation model. JGR-Atmospheres, accepted.**
  - **Chéruy F, Campoy A, Dupont J-C, Ducharne A, Hourdin F, Haeffelin M, Chiriaco M, Idelkadi A (2013). Combined influence of atmospheric physics and soil hydrology on the simulated meteorology at the SIRTA atmospheric observatory. Climate Dynamics, 40, 2251-2269, doi:10.1007/s00382-012-1469-y**
  - **F. Chéruy, A. Campoy, A. Ducharne, F. Hourdin, J.C. Dupont: Possible cause and cure for the warm biais in the CMIP5 mid-latitude summer simulations, 4th WGNE workshop on systematic errors in weather and climate models, 15-19 Avril 2013, Exeter (UK).**
  - **Chéruy F, Campoy A, Ducharne A, Hourdin F, Ghattas J, Dupont J-C, Idelkadi A. Rôle de l'hydrologie continentale dans le climat au voisinage de la surface aux moyennes latitudes. Ateliers de Modélisation de l'Atmosphère, 21-25 janvier 2013, Toulouse, France**
  - **Ducharne A, Guimberteau M, Campoy A, Polcher J, Cheruy F, Vuichard N, Solyga D, Maignan F, Ottlé C, Peylin P, Mancip M, Ghattas J. Vers une unification de l'hydrologie des sols dans le modèle de surface continentale ORCHIDEE, Ateliers de Modélisation de l'Atmosphère, 21-25 janvier 2013, Toulouse, France.**
  - **Ducharne A, Polcher J, Guimberteau M, Campy A, Chéruy F, Vuichard N, Ottlé C, Verbeeck H, et al. Terrestrial hydrology in ORCHIDEE - Past achievements and perspectives, Journées ORCHIDEE, 13-14 mai 2013, Paris, France.**

- **SISYPHE Project - HydrOracle project : Analysis of regional hydrogeological simulations using ORCHIDEE water fluxes prior to study the impact of both climate and land use changes within the framework of the Oracle ANR project**

SISYPHE contacts : Florence Habets, Sisyphe, florence.habets@mines-paristech.fr
Sandro Rinaldi, Sisyphe, sandro.rinaldi@mines-paristech.fr
LSCE contact : Nathalie de Noblet, nathalie.de-noblet@lsce.ipsl.fr

CONTEXT

The project aimed assessing the water fluxes simulated by ORCHIDEE on a large french basin by using an existing hydrogeological modeling that allows computing the daily riverflows and piezometric heads. This was a necessary step to a larger projet, the ORACLE ANR project, wich aims estimating the evolution of the land use in France according to the constraints from climate change, economy, and availability of the water resource.

To do so, Sandro Rinaldi was hired as a post doc, and we selected a simulation of ORCHIDEE that was made using the SAFRAN-France analysis forcing, and that has already been compared to a similar simulation from the ISBA land surface scheme (Lafont et al., 2012). Such choice has allowed a wider intercomparison on the two land surface schemes water balance, but has limited the work to the Seine basin, as the extension to the Rhine basin would have make it necessary to run new simulations to encompass the german part of the Rhine basin.

METHOD

The 14-year of simulated daily surface runoff and drainage from ORCHIDEE and ISBA (1994-2007) were providing as an input to the hydrogeological application of the Seine basin performed with the MODCOU model (Viennot 2012). MODCOU explicitly simulates the water transfer in the unsaturated zone, 6 aquifer layers, and the rivers. Thus, the assessment of the simulated riverflows and piezometric heads on about 100 gages; and the comparison of the water balance estimated by the 3 models were made.

RESULTS

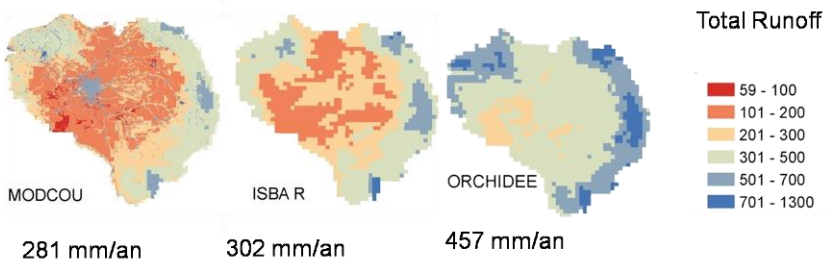


Figure 1 : Comparison of the mean annual total runoff simulated by MODCOU, ISBA et ORCHIDEE over the Seine basin.

Orchidee has 50% more total runoff than MODCOU and ISBA, and, consistently, less evaporation

(Figure 1). This leads to an overestimation of the riverflow, since 80% of the river gages have a discharge overestimated by up to 50% (Figure 2a). This overestimation also affects the statistical criteria, and for instance; the daily efficiency is positive only for 10% of the river gages (Figure 2b). The results are thus clearly poorer for ORCHIDEE than for MODCOU or ISBA[2].

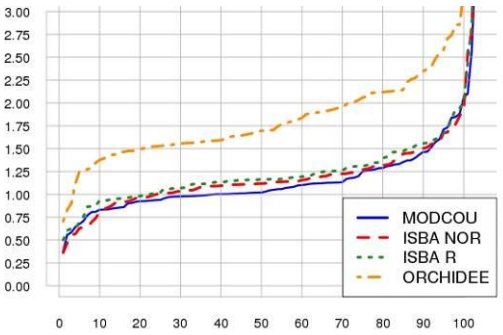


Figure 2a) Comparison of the ration of the simulated over observed discharge on the 104 river gages (a perfect model would obtained a value of one for all gages).

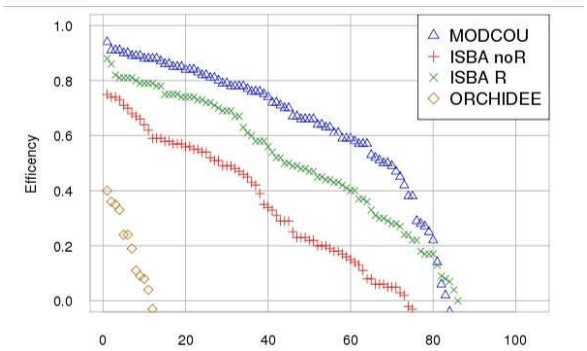


Figure 2b) Comparison of the daily efficiency on the 104 river gages (a perfect model would obtained a value of 1 for all gages)

Similar results are obtained for the piezometric heads: Orchidee overestimates the piezometric heads by up to 2 m on 80% of the wells (Figure 3), while such error is reached only for 30% of the wells by the 2 other models.

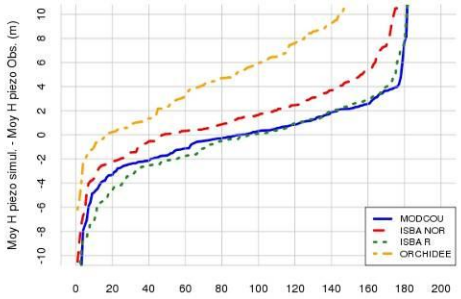


Figure 3 : Comparison of the piezometric bias computed on the 180 wells. A perfect model would obtaine a value of 0 for all wells.

[2] Two versions of ISBA were analysed :a version without subgrid surface runoff (ISBA-NOR), identical to the one analysed in Lafont et al., 2012, and one with the parametrisation of subgrid surface runoff activated (ISBA-R).

- **ANALYSIS**

Although MODCOU and SURFEX use very different physics to compute the water balance[3], they obtained similar partition of the precipitation in evaporation and total runoff, which are also quite in agreement with the observed riverflow. In order to better understand the origin of the overestimation of the riverflow by ORCHIDEE, a deeper analysis of the component of the water balance was done. Figure 4 presents the mean monthly evolution of the PET and actual evaporation computed by the 3 models. The actual evaporation computed by ORCHIDEE is always smaller than the 2 others. In order to perform a deeper analysis, we focused on the components of the actual evaporation for each functional plant, and as no observation are available for such fluxes, the comparison was made only with the estimation from ISBA.

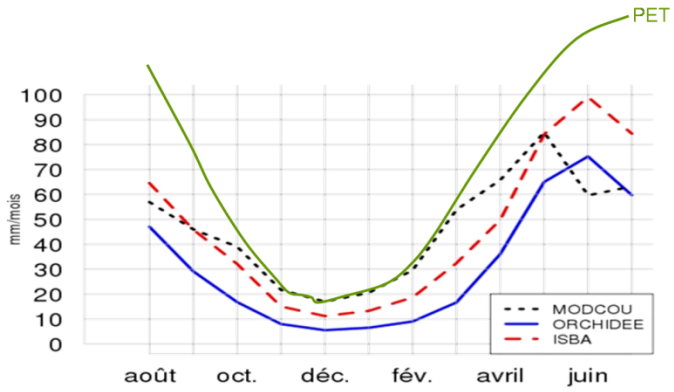


Figure 4 : comparison between the monthly potential evapotranspiration (PET in green) and the actual evapotranspiration simulated by the 3 models.

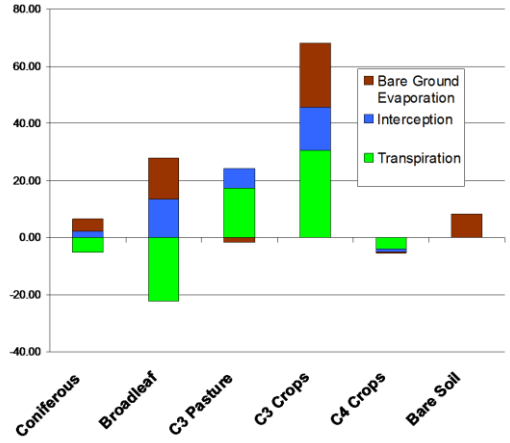


Figure 5 : Percentage of the total difference of the actual evaporation between ISBA and ORCHIDEE associated to each functional plant and each evaporation component.

The main differences are obtained for the C3 crops (Figure 5). It was found that this is partly due to an imposed cutting of the C3 crops in June with ORCHIDEE (in order to represent the harvesting of the wheat). Moreover, a large part of the difference is also linked to bare soil evaporation and interception which are always weaker in ORCHIDEE than in ISBA.

[3] MODCOU uses a reservoir model to compute the water balance with daily input of Precipitation and potential evapotranspiration.

- **CONCLUSION**

The study has shown an overestimation of the total runoff and an under estimation of the actual evaporation in this simulation of ORCHIDEE. However, this simulation of ORCHIDEE was not made using the usual framework, since the spatial repartition of the functional plant was modified according to the ECOCLIMAP II database, in order to allow a comparison with ISBA (Lafont et al., 2012). It is possible that these modifications have generated errors. A new simulation of ORCHIDEE using the SAFRAN atmospheric forcing but classical vegetation map will be run in order to see if the results are then improved. This will be done in the framework of the ORACLE ANR Project.

- **VALORISATION**

This study is presented in a full report (Rinaldi et al., 2013 67p), which is closed to its final form, and that will be made available on the Oracle web site (https://oracle.lsce.ipsl.fr). This study was presented during the ORCHIDEE meeting in May 2013.

- **REFERENCES**

- **Lafont, S., Zhao, Y.,Calvet, J.-C., Peylin, P.,Ciais, P., Maignan, F., and Weiss, M.. Modelling LAI, surface water and carbon fluxes at high-resolution over France: comparison of ISBA-A-gs and ORCHIDEE. Biogeosciences, doi:10.5194/bg-9-439-2012, 2012.**
- **Viennot P., Habets F., Modélisation du bassin de la Seine, Rapport du projet Explore 2070 (http://www.developpement-durable.gouv.fr/Hydrologie-souterraine.html)**

Infrastructure projects for TWP1 and TWP2

- **TWP1 contribution to the initial Labex L-IPSL program**
- **TWP2 contribution to the initial Labex L-IPSL program**

- ## TWP1 contribution to the initial Labex L-IPSL program

CMIP model intercomparison projects are organized by the world climate research program (WCRP) to advance our knowledge of climate variability and climate change. The results obtained thanks to CMIP provide essential inputs to the IPCC reports. Thanks to the climate models developed in house for the last twenty years, the IPSL contributes to the fifth phase of this model intercomparison project for the first time side by side with the major international research groups (Figure 1). The CMIP5 model outputs constitute an exceptional database used by climate centers to investigate the climate, climate change and the impact of climate change. CMIP5 includes an unprecedented ensemble of experiments including current (1979-2009), future (up to 2300), recent (from 1850) and paleo climate (Figure 2), with different model configurations, from idealized atmosphere only experiments to experiments with Earth System Models (coupled atmosphere-ocean models including carbon cycle, chemistry and aerosols).

To fully benefit from this database, an infrastructure has been implemented by IPSL. It includes a very large storage capacity and computing resources relevant for the analysis of large datasets. The IPSL has also developed tools to gather, document, and update the CMIP5 data (from IPSL models and other climate models).

The Labex has allowed the TWP1 group to facilitate distribution and analysis of CMIP5 data by :

1. Increasing the disk space dedicated to storage and analysis (currently 400 To). The IPSL model outputs and subsets of other model outputs can now be stored on this disk space;
2. Documenting all versions of IPSL model outputs, the detected errors, and the associated corrections. This information is available on Internet and tools have been developed to allow users to check the status of their data. About 140.000 files are currently available as well as the corrections regarding 24.000 of them;
3. Developing tools to facilitate the use of this very large dataset. These tools allow users to retrieve all CMIP5 model outputs, their evaluation, their updates, and their storage within a single directory structure. Tools to aggregate a group of files in order to use them as a single file have also been developed. They allow computing and visualization scripts to process a large number of files more easily;
4. Giving free access to three reference publications for the CMIP5 simulations with the IPSL model. The publications describe the main model characteristics, the forcing and the reference simulations.

The CMIP5 data is widely used. Researchers at the IPSL have already published tens of publications analyzing this dataset and many more are in preparation at the institute. Research groups outside of the IPSL download the IPSL model outputs at an extremely rapid rate (typically, 30.000 files and 30 To of data per month).

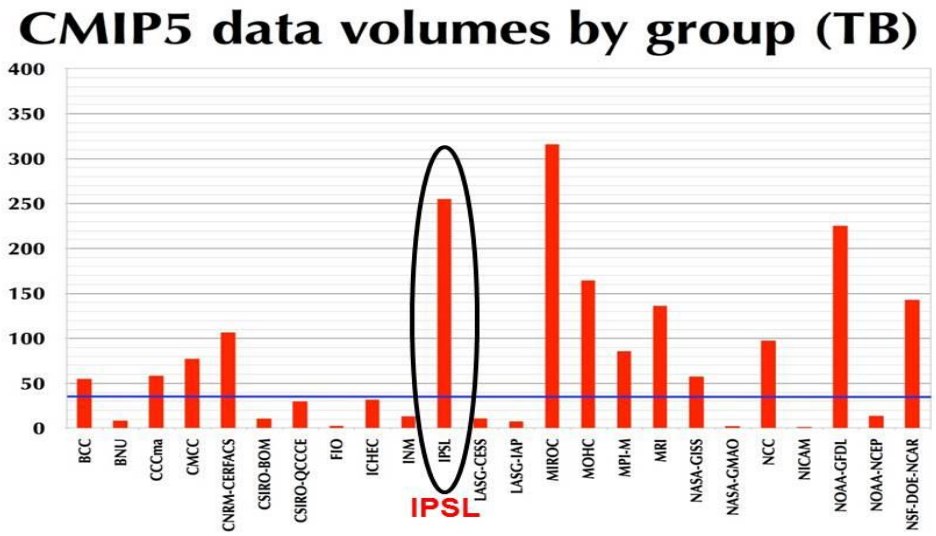


Figure 1 : Volume (in Tera byte) of the data provided by the various climate modeling centers that contribute to the CMIP5 project (update: October 2012)

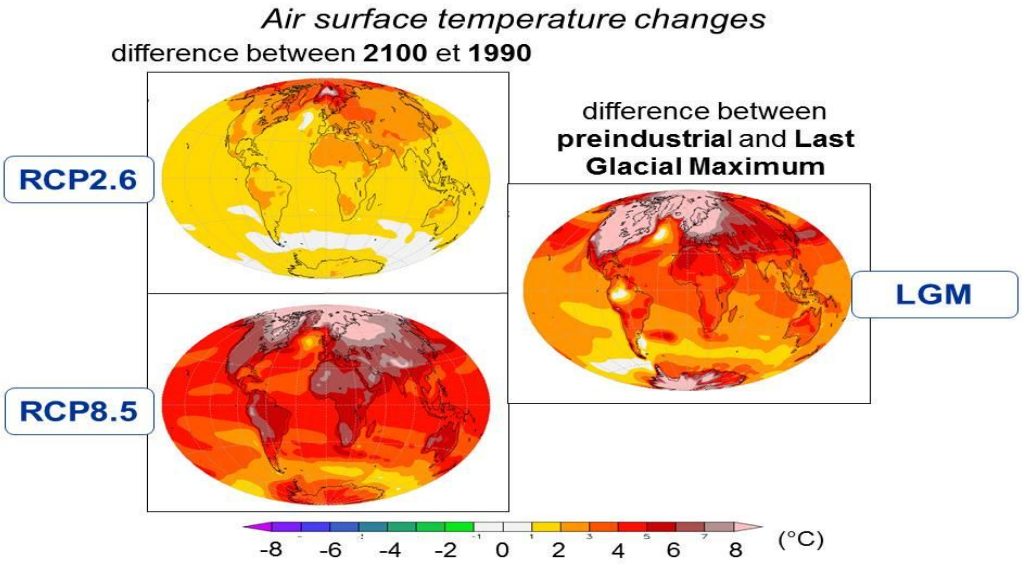


Figure 2 : Difference of air surface temperature computed by the IPSL-CM5A-LR model between future (year 2100) and current climate for two scenarios (left column) and between the preindustrial and the last glacial maximum (LGM) period (right column)

- ## TWP2 contribution to the initial Labex L-IPSL program

Mise à disposition des observations de niveau 3

De nombreuses analyses des observations depuis le sol ou l'espace conduisent à établir des climatologies, des tendances, des biais entre jeux de données ou des statistiques d'occurrence d'évènements liés au climat ou à la pollution. Ces résultats font l'objet de publications mais ne sont pas toujours connus de ceux qui sont impliqués dans la modélisation numériques et qui ont besoin de ces résultats pour valider/comparer la modélisation et les observations sur des bases statistiques. Les résultats ne sont aussi pas toujours disponibles sous une forme numérique adéquate pour être exploités par d'autres scientifiques.

Objectif

Le projet consiste à mettre à disposition ces jeux de données avec, un rapide texte décrivant pour une communauté assez large le produit disponible, les représentations graphiques, la(les) publication(s) associée(s), les sources des données (liens vers les centres d'archivage) et une explication sur le type de données de base ou de l'instrument les ayant produites, des contacts scientifiques et enfin toutes les explications supplémentaires permettant de mieux comprendre comment ce produit a été obtenu et comment l'utiliser de manière adéquate. Il est proposé d'organiser ces produits par variable: nuages, aérosols, temperature, vapeur d'eau, ozone, autres gaz.

Travail attendu

- Développer une charte graphique et une organisation de cette base de données.
- Travailler avec les chercheurs pour récupérer l'information
- Organiser l'information sur une page web en lien avec le projet IPSL/ESPRI

Pour réaliser ce projet, un CDD d'un an ingénieur de niveau IE est recruté. Le projet n'étant pas encore terminé le rapport final du projet sera élaboré dans les mois qui viennent.

Appendix B : L-IPSL Labex Post-doc/Engineer projects and profiles

This section includes 6 of the planned 7 post-doc/Engineer project and profiles, as selected in the action plan 2012. The 7th one concerns an engineer position for TWP1 that will start early 2014 and is not currently available, but will be available by the end of the year.

- **Project 1 (WP1-WP3-WP4) : L-IPSL post-doctoral fellow offer in biogeochemistry and hydrology**

Title: Modeling inland water greenhouse gas fluxes

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 2 years to integrate into the IPSL Earth System Model some of the key previously neglected inland aquatic processes than form the so called "boundless carbon cycle". The proposed post-doctoral position project is a reaction to the growing awareness that inland waters contribute significantly to global greenhouse gas (GHG) fluxes, and to the realization that their sensitivity to projected climate change and eco-hydrological disturbance is poorly constrained.

Context : The conventional wisdom is that inland waters simply transport terrigenous organic carbon to the oceans. This view is perpetuated by current models of the global carbon cycle that largely ignore inland waters as represented in, for instance, the Intergovernmental Panel for Climate Change (IPCC) – Fourth Assessment Report (FAR), or the Integrated Global Observing Strategy report (GEO-Carbon). In the five years since the publication of IPCC's FAR in 2007, it has become apparent that the global flux of GHGs from inland aquatic sources to the atmosphere is much larger than previously suspected (Battin et al., 2008; 2009; Butman and Raymond, 2011; Bastviken et al., 2011; Barros et al., 2011). Thus, recently published estimates indicate that inland waters degas from 0.8 Pg (1Pg= 109 metric tons) of carbon per year (excluding wetlands, Cole et al. 2007), up to 3.3 Pg C y-1 (including wetlands, Tranvik et al., 2009; Battin et al., 2008; 2009; Aufdenkampe et al., 2011; Butman and Raymond, 2011), the latter estimate of similar magnitude to the terrestrial carbon sink of 2.8 Pg C y-1 (Canadell et al. 2008). Only recently have regional scale carbon balances begun to consider these fluxes (e.g. Luyssaert et al., 2012), but large knowledge gaps remain concerning their magnitude and their ultimate significance for global carbon cycle models. Current estimates based on global surveys and 'bottom up' extrapolations from streams and rivers in the United States for example indicate that this GHG flux is significant relative to the total anthropogenic flux of carbon to the atmosphere, with emissions from the northern hemisphere temperate zone (25oN-50oN) rivers alone estimated to be c. 0.5 Pg annually (Butman and Raymond, 2011). Additionally, a recent survey of CH4 emissions from inland aquatic systems (lakes, reservoirs and rivers) indicated annual CO2-equivalent methane emissions of a similar magnitude (0.65 Pg of C as CO2 equivalent; Bastviken et al., 2011). These recent estimates necessitate a paradigm shift from the traditional depiction of streams, rivers and other inland freshwater bodies as inert conduits and reservoirs, to one in which the kinetics of climate-sensitive GHG production by aquatic biogeochemical transformation reactions, hydrologically driven soil gas flushing from riparian zones and the dynamics of gas transfer processes at water/air interfaces are incorporated into realistic 'boundless carbon cycle' models.

Despite the potential importance of these GHG emissions, their inclusion, even under a simplified form, in current Earth System Models is still missing, although several research teams began to work in that direction. The sensitivity of lateral C fluxes in aquatic systems to global change and eco-hydrological disturbances is largely unknown, and their overall significance for Earth's global carbon budget remains to be established as well. Much previous work on regional scale carbon balances has focused on terrestrial sinks and sources, but it is increasingly appreciated that flux measurement techniques that are applied widely to terrestrial systems (e.g. Eddy covariance methods) are inappropriate or require re-evaluation for aquatic systems.

Description of work: The postdoctoral fellow will interact with researchers at LSCE and SISYPHE laboratories, part of L-IPSL, and incorporate a set of simplified parameterizations on the land surface scheme ORCHIDEE of the IPSL Earth System model the following processes : C emissions from soils to

rivers headstreams for DIC and DOC, with a highly parametric inclusion of chemical alteration fluxes of C from atmospheric origin, CO2 evasion data from rivers and floodplains, C burial in lakes and freshwater sediments and CO2 emissions from estuaries (the later using the global upscaling model developped by Pierre Regnier at University of Utrecht). The ORCHIDEE model enabled for carbon transport from soil to rivers and lakes will be tested and calibrated against a new pCO2 global database and river fluxes of DOC, DIC (COSCAT database of 150 catchments; http://www.agu.org/pubs/crossref/2006/2005GB002540.shtml). The model will be applied in the second year for characterising the presently unknown atmospheric feedbacks (positive and negative) between inland aquatic carbon evasion fluxes and drivers such as climate change and anthropogenic eco-hydrological disturbance.

Supervision team: The researcher with a PhD in earth system science, will be hired by CNRS and will be hosted at LSCE in Saclay while working in close collaboration with SISYPHE in Paris. The work will be in a project team led by Philippe Ciais, including also Laurent Bopp, Josette Garnier, Sebastiaan Luyssaert and Christophe Rabouille.

Duration and salary: The post-doctorate will be recruited for 24 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a vita, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Philippe Ciais (philippe.ciais@lsce.ipsl.fr).

- **Project 2 (WP2) : L-IPSL post-doctoral fellow offer in volcanism and climate**

Title: Volcanism during the last millenium

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 2 years to address impacts of volcanism on climate in the last millenium.

Context: It is now generally recognised that volcanic eruptions have an important effect on climate variability from inter-annual to decadal timescales. Using comprehensive Earth system models, much progress in understanding volcanic climate effects have been achieved in recent years, including the impacts on atmospheric chemistry and dynamics, on ocean dynamics, marine and terrestrial biochemistry and on the hydrological cycle. These results are however hampered by many assumptions on the reconstructed past volcanic activity, but also on the choice on sulphate aerosol size distribution and their implementation in the radiation scheme of models themselves. Several outstanding questions remain and concern the behaviour of huge SO_2 cloud injected into the stratosphere after super eruptions such as those that did occur during the last centuries.

Description of work: All in all, these results call for more process-oriented sensitivity experiments. The challenging task for the hired post-doctoral fellow would be to improve the actual volcanic forcing reconstructions and its implementation in the IPSL models. As a first step, the focus will be on the calculation of the temporal evolution of volcanic aerosol size distribution, global fields, and optical characteristics, for the two biggest volcanic eruptions of the last millennium, i.e. the 1258 AD and the Tambora (1815). Such calculations will be done with a global 2-D stratospheric climate model including detailed microphysical and chemical processes for stratospheric volcanic aerosols. This model has been developed at the LATMOS laboratory (IPSL). New estimates of SO_2 release are now available for these two eruptions and will be used to constrain the SO_2 loading in the 2-D model. This will allow the calculation of (1) consistent evolution of the global distribution and size of stratospheric sulphate aerosols after each eruption and (2) deduce the related optical properties (AOD, single scattering albedo and parameters of asymmetry) for both v*isible* and *infrared* spectral bands.

In a second step and in collaboration with LMD laboratory (IPSL), the deduced new size distribution and optical parameters will be implemented into the LMDz radiation scheme for both spectral bands (visible and infrared). Sensitivity experiments with chemistry-climate models (CCM), LMDz-REPROBUS and/or LMDz-INCA, coupled to NEMO, including the new stratospheric aerosol radiation schemes will then be used to run sensitivity experiments and evaluate the impact of competing non-linear radiative and chemical processes on the simulated climates for volcanic eruptions. We will start by a test case, simulating the Mont Pinatubo eruption in the CCM model. The results will be validated against the large datasets of observations (satellite, balloon, reanalysis,…) and serve as a reference control run. Then we will tackle the two biggest volcanic eruptions for the last millennium (i.e. 1815, 1258 AD).

In the last step, cross validations of the sensitivity experiments for the mega eruptions with proxy data will be essential to better evaluate the realism of the new volcanic forcing parameterisation for the largest eruptions. More proxy reconstructions are now available at

IPSL (LSCE, LOCEAN, etc.) and in other national and international laboratories. They will help constrain the climate sensitivity. In interaction with the LOCEAN laboratory (IPSL), further tests will be required on the influence of the initial state (including the ocean) on the simulated climatic response following these volcanic eruptions before extending our approach to the whole millennium.

Supervision team : The work will be conducted under the main supervision of M. Khodri (LOCEAN), in close connection with other researchers : M. Marchand (LATMOS), S. Bekki (LATMOS), O. Boucher (LMD), J. Mignot (LOCEAN), D. Swingedouw (LSCE). The work will be mainly conducted at LOCEAN, but in other IPSL sites also.

Duration and salary: The post-doctorate will be recruited for 24 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a vita, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Myriam Khodri (Myriam.Khodri@ird.fr).

- ## Project 3 (WP4-WP3-TWP3) : L-IPSL post-doctoral fellow offer in climate change impacts

Title: Assessing the robustness of multi-region and multi-sectoral indicators of climate change impacts

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 2 years to assess impacts of climate change in various sectors and regions of the world.

Context: The Fourth Assessment Report of the Intergovernmental Panel on Climate Change has, with greater confidence than previous reports, warned the international community that the increase in anthropogenic greenhouse gases emissions will result in global climate change with potential impacts on natural resources, ecosystems and human's activities. Thus, there is a growing literature on the impacts of climate change, mostly using global climate models (GCM) projections to drive process-based or statistical impact models. However, very large uncertainties remain between impact studies, reflecting the diversity of such studies, which often focus on different locations, and rely on different climate projections (models, scenarios), type of impacts and impacts models, downscaling techniques, time horizons, etc.

Description of work: We therefore propose a coherent multi-region and multi-sectoral approach to examine the robustness of projected impacts driven by IPSL-CMIP5 climate change scenarios. Various downscaling methods (delta method, CDFt, homogenous climatic zones, CORDEX dynamical downscaling, and use of raw GCM outputs) will be used in order to assess knowledge and uncertainty in impacts projections among sectors and regions of the globe. This work is part of the Labex L-IPSL project which aims at improving our knowledge on climate change and to anticipate its impacts on nature and society.

The recruited post-doctorate fellow will participate to the selection of a set of indicators of impacts of climate change on prone sectors and regions. This part of the task implies a very close collaboration with all L-IPSL partners. He/she will be in charge of downscaling IPSL-CMIP5 climate change scenarios with various existing methods (most of them have already been implemented at IPSL). He/she will then use several impacts models developed or used by the l-IPSL teams, including the land surface model ORCHIDEE, to produce maps of relevant indicators of climate change impacts and to analyze the robustness of such impacts projections in regards to the used downscaling method. Experience in biosphere modelling, statistical analysis and linux environment will be greatly appreciated.

Supervision team: The work will be conducted at LOCEAN/IPSL located at University Pierre and Marie Curie (4 place Jussieu, Paris 05), under the main supervision of B. Sultan (LOCEAN) and in close connection with other researchers of LSCE (P. Braconnot, M. Vrac, N. De Noblet, O. Bopp), SISYPHE (A. Ducharne), LATMOS (C. Flamant) and in the L-IPSL project.

Duration and salary: The post-doctorate will be recruited for 24 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a vita, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Benjamin Sultan (Benjamin.sultan@locean-ipsl.upmc.fr).

- **Project 4 (WP5) : L-IPSL post-doctoral fellow offer in development of integrated, multi-archive chronologies**

Title: Developing and testing integrated, multi-archive chronologies to improve our understanding of past, rapid climate changes and bifurcations.

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 2 years to join a collaborative effort involving specialists of ice, continent and marine climatic records and aimed at putting key archives into a common chronological framework in order to improve our understanding of past, rapid climate changes.

Context: Understanding the mechanisms at the heart of rapid climate changes and major bifurcations recorded in paleoclimatic archives requires that we are able to resolve accurately minute leads/lags in order to fully understand signal propagation and identify feedbacks across the various compartments of the earth climatic system. This requires to put ice, marine and continent paleo-records into a common chronological framework, with an unprecedented accuracy and with a clear understanding of uncertainties associated to the various approaches used to define tie-points (e.g. ^{14}C, ash layers, ^{10}Be, magnetic field paleo-intensity,..). Such an effort is mandatory if one wants to test the robustness of climate scenarios. The synchronization of ice records over the last 800 kyr (AICC2012 chronology, special issue of *Climate of the Past*) has been recently achieved through an inverse *Bayesian* assimilation approach. The DATICE tool (http://datice.gforge.inria.fr/) formulates a variational inverse problem, which aims at correcting the main parameters associated with the ice core timescales (e.g. accumulation, thinning) through integration of absolute and stratigraphic tie-points. The next step is to adapt this powerful tool to different archives and use it to develop and test chronologies for key continental and marine archives, and insure their optimal synchronization, in connection with ice records.

Description of work: To reach these goals, we propose to adapt the DATICE tool to continental and marine records (e.g. dealing with potential hiatuses, integrating archive-specific accumulation rate scenarios, …). Then, the DATICE tool will be used on key, high-resolution, multi-proxy paleo-climate records (1) to develop and test possible chronologies, (2) to carefully analyze uncertainties and limitations, and (3) to conduct inter-archive comparisons and address climatic implications once an optimal synchronization has been achieved. In accordance with the main goals identified for L-IPSL mid-term objectives, a special effort will be devoted to study mid- and high-latitude records around the North Atlantic (including the Mediterranean Sea) and the Nordic Seas, but other areas will also be explored as part of several on-going research projects of L-IPSL groups (i.e. monsoon variability).

The post-doctorate fellow will participate to the selection of key, high-resolution archives. He/she will be in charge of modifying the DATICE tool in order to take into account the specificity of the different continental and marine archives used. He/she will be at the heart of the chronological development with DATICE in close collaboration with the specialists. He/she will train those interested in using DATICE. He/she will be involved in the maturation and publication of paleo-climatic interpretations based upon the improved chronologies.

A solid experience in programing and data assimilation (i.e. Bayesian statistic) is mandatory, as well as good general knowledge of climatic archives.

Supervision team: The work will be conducted at LSCE/IPSL under the main supervision of A. Landais and C. Waelbroeck, and in close connection with other researchers of LSCE (F. Bassinot, D. Blamart, D. Genty, H. Guillou, C. Hatté, C. Kissel, V. Mason, E. Michel, M.A. Sicre,..), LOCEAN (AM Lézine, B. Turcq, D. Wirrman..), IDES (C. Colin, S. Sepulcre, G. Siani, S. Duchamp-Alphonse,...) and in the L-IPSL

project.

Duration and salary: The post-doctorate will be recruited for 24 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a vita, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to A. Landais (Amaelle.Landais@lsce.ipsl.fr) and C. Waelbroeck (Claire.Waelbroeck@lsce.ipsl.fr).

- **Project 5 (TWP2-WP3) : L-IPSL position to develop an Arctic data portal**

Title: Arctic Data Portal

The laboratory of excellence L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 1 year to develop an L-IPSL Arctic data portal.

Context: The Arctic is undergoing unprecedented changes as a result of global warming such as the rapid decline in summer sea-ice. However, the reasons for such changes and their impacts on the environment and society are not well understood thereby limiting our ability to predict what might happen in the future. In particular, the performance of global climate models needs improving including treatments of many processes and their interactions within the atmosphere-ocean-ice-biosphere system. Process-based studies based on a combination of analysis of available data and models of varying complexity/scales will lead to improvements in climate models. The Arctic has been highlighted as a research priority within L-IPSL and nationally with the creation of the French Chantier Arctique.

Description of work: Many different datasets exist at L-IPSL collected as part of different projects examining a wide range of scientific issues in the Arctic. These include projects studying atmospheric, ocean, biogeochemical processes as well as pollution, permafrost, glaciers, sea-ice etc. In order to promote new avenues in Arctic research within IPSL and to improve Arctic modelling capabilities, L-IPSL is creating an Arctic data portal. In the first instance, the aim is that this data portal will provide links to existing datasets including information about each dataset using a user-friendly web-based environment. It will contain information about different regions and types of data (ground-based, marine, aircraft, satellite). In a second phase, a data policy will be developed to facilitate the use of datasets for the evaluation of models at IPSL, including the global IPSL climate model and regional models. Modelling results may also be incorporated into the data portal.

Supervision team: The work will be conducted under the main supervision of P. Keckhut (IPSL) and K. Law (LATMOS) and carried out in close collaboration with the IPSL data management team as part of the ESPRI project (in particular, at LMD/Palaiseau). The work will be carried out at LATMOS in Guyancourt, west of Paris where the Observatoire Versailles and Saint Quentin (OVSQ) Arctic network is also based.

Expertise: Persons with expertise in geophysical data management who are motivated to work on scientific issues in the Arctic are invited to apply. Good written and spoken English is required together a willingness to interact and discuss with different groups. Applications from people with research experience in the Arctic are also welcome. Experience in computing is also useful.

Duration and salary: The researcher (master level upwards) will be recruited for 12 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a CV, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers.

Applications should be submitted by e-mail to Philippe.Keckhut@latmos.ipsl.fr and Kathy.Law@latmos.ipsl.fr.

- **Project 6 (TWP2-WP5) : L-IPSL post-doctoral fellow offer in isotopic geochemistry**

Title: Water Isotope database: present and past archives

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers a post-doctoral position of 2 years to build a database on ^{18}O and D isotopes combining observations and simulations at various time-scales.

Context : Water stable isotopes are a powerful tool to decipher the hydrological cycle at global and local scales. The objectives of this project are:

- to obtain a global vision of isotopic changes for well documented past periods (6kyrs, LGM, Eemian, DO events,…) and to better interpret isotopic proxies in terms of climate change.

- to better understand the differences between data and models: are they related to the representation of processes? to different spatial (horizontal and/or vertical) scales between the data point and the model grid?

- to better understand the factors controlling past isotopic evolutions in ice, carbonate and sediment archives. A forward proxy modeling will be developed for better quantify the relative influence of different climate parameters.

Description of work : This work is part of the Labex L-IPSL project which aims at improving our knowledge on climate change and to anticipate its impacts on nature and society The main tool to be developed is a database on ð18O and ðD grouping data (instrumental and paleoclimate archives) and model simulations at different time scales. The activities include:

- synthesis of precipitation and sea water observational data for the instrumental period prolonged for the period of historical simulations (1800-2010) by tree-rings, ice cores, speleothems and coral data;

- synthesis of paleo-data, beginning with continental data, for key periods of the past (6k, Eemian, ..) or transition period where simulations are (will be) available (6 – 2k, D/O, Late Glacial,…). A link with two other IPSL projects concerning LGM and water vapor must also be developed.

- making available simulated equivalents for each data point, at least for IPSL models.

The recruited post-doctorate fellow will have to gather the data and discuss their validity/uncertainty for isotope value and chronology. A close collaboration with IPSL researchers will be necessary for this task that, certainly, will lead to the production of scientific publications. An experience in isotope geochemistry is required for this project.

Supervision team: The work will be conducted at LSCE/IPSL, under the main supervision of V. Masson-Delmotte and in close connection with other researchers: Françoise Vimeux (Water Vapor), Laurence Gourcy (Precipitations), Camille Risi (Atmosphere Modeling), Jean Claude Dutay (Ocean Modeling); Catherine Pierre (Ocean Data), Valerie Daux (Tree Rings), Dominique Genty (Speleothems), Claire Waelbroeck (Ocean Cores), Didier Roche (Glacial Periods), Laurent Bergonzini (Lakes), Bruno Turcq (Paleo-monsoon), Bruno Malaize (Lake Sediment).

Duration and salary: The post-doctorate will be recruited at least for 12 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a CV, a statement of research interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to Valérie Masson-Delmotte (Valerie.Masson@lsce.ipsl.fr).

- **Project 7 (TWP1) : L-IPSL engineer position offer in development of a stretched version of the IPSL Earth system model**

Title: Developing and testing of a stretched version of the IPSL Earth system model

The excellence laboratory L-IPSL of the Institut Pierre-Simon Laplace offers an engineer position of 1 year to join a collaborative effort involving the IPSL climate model development team in order to develop and customize the use of a stretched versions of the IPSL-ESM. The scientific goal behind this development is to simulate the climate at the regional scale for past, present and future climate conditions, and to allow the analysis the interactions between global and regional climate and between climate and biogeochemistry cycles.

Context: Simulating the climate at regional scale at higher horizontal resolution than that of usual global climate models is of high interest. This allows to better represent the orthographic effects and facilitates the comparison between model and local observations. This higher resolution can be obtained by using global models at very high resolution or by limited-area models. Each of these methods has its strengths and weaknesses. An attractive and alternative method is to use global models with stretched grid.

The IPSL-CM5 model is and Earth System Model that includes a representation of the physical and the biogeochemistry (carbon cycle, aerosols, chemistry...) processes at the global scale, for both the atmosphere, land surface, ocean and sea-ice. The atmospheric component, LMDZ, has a stretchable longitude-latitude grid that allows refinement of the horizontal grid over any specific region. The objective of the proposed work is to develop tools that allow an easy use of this refinement capability over any continental regions and for the various configurations of this ESM.

Description of work: In order to make effective an customize the use of the LMDZ “zoom” capability in the IPSL-ESM system, it is necessary to develop an ensemble of generic tools. This should include in particular interpolation procedures on the zoomed grid, as well as the development and upgrade of scripts that automatically downwoad the required input datasets, interpolate the data on the model grid, and run the simulations. The work will be done in three main steps: (1) creation of the zoom, the initial states and interpolation of all the variables necessary to drive the physical part of the model with prescribed SST (2) interpolation of all the variables necessary to drive the biogeochemistry part of the model over continents with prescribed SST and (3) same but with a coupling with the ocean and sea-ice. Two regions will be used for benchmarking in link with project that involve the IPSL-ESM team: Europe and West Africa.

The candidate should have a solid experience in FORTRAN and shell programing and a good general knowledge in climate modeling.

Supervision team: The work will be conducted at IPSL under the main supervision of J-L Dufresne, M-A Foujols and A. Caubel, and in close connection with other researchers and engineer of the IPSL Climate Modeling Center, from IPSL (J. Ghatas, S. Denvil, P. Cadule), LMD (F. Hourdin, L. Fairhead, F. Cheruy), LSCE (A. Cozic, P. Peylin).

Duration and salary: The engineer will be recruited for 12 months with a net monthly salary around 2000 euros, commensurate with experience. This includes social services and health insurance.

Contact for applications: Applications should include a vita, a statement of interests and the names of at least two references including e-mail addresses and telephone numbers. Applications should be submitted by e-mail to J-L Dufresne (Jean-Louis.Dufresne@lmd.jussieu.fr).

Appendix C (in French) : Innovation et transfert

Propositions pour la valorisation et le transfert de l'information climatique pour l'adaptation

Plan d'actions à moyen terme

• Objectifs en bref

Ce document, de nature interne à l'IPSL, a pour objectif de proposer une stratégie pour l'IPSL dans le domaine du transfert d'informations climatiques pour l'adaptation, souvent appelés « services climatiques », et de proposer quelques actions qui pourraient être mises en place à l'échéance de 2 ans par le LABEX L-IPSL en lien avec les autres actions déjà engagées. Le fil conducteur de la stratégie développée ici est de permettre une meilleure diffusion et utilisation des données de simulation climatique en se basant sur les travaux et productions déjà réalisés au sein des équipes de l'IPSL à travers plusieurs actions :

- **la mise à disposition de données de simulations climatiques de « niveau 1 »: accès CMIP5 et CORDEX, et service d'aide à l'exploitation des données via PRODIGUER ;**
- **L'accès à des données de « niveau 2,3 » : projections climatiques débiaisées, indicateurs (si possible génériques) qui devront être développés ;**
- **L'accès aux suites logicielles (post-traitement, downscaling statistique, débiaisage des sorties de modèles par rapport au climat actuel, production d'indicateurs, estimation des fréquences d'occurrence d'extrêmes climatiques, modèles d'impact) développées à l'IPSL**

Afin de mettre en œuvre ce plan d'actions, nous avons constitué une « cellule de mobilisation » pour la valorisation des données, le développement de projets avec des utilisateurs et des PMEs et la constitution d'un réseau de partenaires extérieurs.

• Les services climatiques et le positionnement de l'IPSL

La notion de « service climatique » correspond au besoin de distribuer ou partager les informations issues de la recherche sur le climat avec d'autres secteurs de l'économie ou communautés de recherche pour le développement de l'adaptation et la mitigation du changement climatique. Il s'agit principalement de la dissémination de sorties de modèles, mais cela peut aussi inclure des outils ou logiciels d'analyse permettant des études plus fines ou encore simplement d'un apport d'expertise.

Les utilisateurs visés peuvent comprendre des acteurs très différents : des communautés de recherche voisines de la communauté « climat », des acteurs publics ou péri-publics, dans le domaine de la négociation climatique, de l'aménagement du territoire, de la législation et de la prise de décision à caractère environnemental, de l'aide au développement, des acteurs privés qui doivent anticiper les effets directs du changement climatique dans les secteurs climato-sensibles de l'économie, etc.

Le besoin de services climatiques a été affirmé au niveau national et international et, par exemple, l'OMM en a fait un axe de développement important de ses activités, qui doit d'abord s'organiser sous forme d'activités pilotes ayant une forte composante de R&D. Le Ministère de l'Ecologie et du Développement Durable suit ces projets avec beaucoup d'attention et organise le lien au niveau international.

Les équipes françaises (en grande partie : Météo-France et l'IPSL, se situant dans le cadre du GT5

d'Allenvi) ont établi un document stratégique commun soumis aux différentes instances d'Allenvi et au Comité Sectoriel de l'ANR où il a reçu un très bon accueil. La stratégie proposée s'appuie en premier lieu sur deux portails de données : DRIAS opéré par Météo-France avec une collaboration de l'IPSL (par exemple via la fourniture de simulations CMIP5+CORDEX réalisées par ses équipes), et PRODIGUER, opéré par l'IPSL, avec une demande de collaboration de Météo-France (par exemple via l'apport des simulations du CNRM et la définition commune de produits). DRIAS est surtout focalisé sur le territoire national et a été conçu pour toucher un public large. PRODIGUER a été conçu en lien avec les programmes internationaux pour distribuer les résultats de modèles globaux (CMIP5) et régionaux (CORDEX). Il est utilisé par une communauté « recherche » importante, internationale, mais son ergonomie est adaptée à un public plus ciblé (recherche et ingénierie d'applications). Le document stratégique met aussi en évidence la nécessité d'une recherche amont vecteur de projets pre-opérationnels innovants (détermination et fabrication d'indices climatiques répondant aux attentes de différents secteurs), et l'importance d'un accompagnement de la diffusion d'information scientifique par un transfert d'expertise.

Participer pleinement au développement des services climatiques est une nécessité vitale pour le développement de l'IPSL – et pour éviter aussi que ces services climatiques se développent en contradiction avec le monde de la recherche. Pour cela, en premier lieu, **l'IPSL doit consolider le développement d'un service de données de qualité avec un niveau d'engagement élevé. PRODIGUER**, qui est une réalisation originale et innovante sur les plans techniques comme dans ses fonctions, est un bon point de départ.

Ensuite, l'IPSL doit mettre à profit l'expertise acquise dans de nombreux projets multidisciplinaires pour développer la recherche sur les indicateurs climatiques les plus adaptés au transfert d'information correspondant à un domaine scientifique large et encore émergent. Le défi est également d'associer connaissance du système climatique, observations, résultats de simulations numériques et méthodes statistiques pour caractériser les indicateurs et les différentes sources d'incertitudes et déterminer les facteurs susceptibles d'être les plus critiques dans le cas d'un changement climatique.

L'IPSL doit pouvoir jouer un rôle d'interface entre le domaine de la recherche et les nombreuses applications qui se déclineront dans différents services climatiques selon l'activité et le public visé. Il doit ainsi développer les liens actifs avec son réseau d'entreprises, et avoir une capacité à :

- fournir des données élaborées et transformées (exemple : indicateurs généralisés sur toutes les données de projections, CMIP5, tous domaines CORDEX, autres…), en cohérence avec le travail réalisé dans les cadres de IS-ENES et GMES-CLIP

- fournir des prototypes de logiciels développés dans les laboratoires (exemple : traitement statistique de séries, débiaisage de jeux de données par rapport au climat actuel et descente d'échelle),

- réaliser des études applicatives « pilotes » avec des industriels et PMEs, mais avec une vocation innovante, c.a.d. non répétitive, et qui auraient un retour scientifique sur la recherche (nouvelles questions originales, etc…).

• Propositions d'actions du Labex L-IPSL à court/moyen terme

Nous détaillons ci-dessous quelques actions concrètes proposées comme déclinaison de la stratégie de l'IPSL dans le domaine de l'information climatique pour l'adaptation. Ces actions sont à développer progressivement mais des objectifs précis peuvent être proposés pour ces deux premières années.

Une cellule de mobilisation pour l'information climatique

L'idée consiste à mettre en place progressivement un petit groupe de chercheurs et ingénieurs volontaires pour travailler à la promotion de la diffusion des informations climatiques (données, accompagnement, conseil, etc…), via le contact avec le monde non-académique (décideurs publics, industriels, PMEs et bureaux d'étude), et qui seraient éventuellement prêts à définir et prendre en main des études pilotes appliquées avec des utilisateurs. Ce groupe permettrait la définition de nouveaux jeux de données, de diagnostics et post-traitements sur les sorties de modèles, ainsi que des indicateurs sectoriels à mettre en place à l'IPSL. Il construirait un réseau d'acteurs extérieurs à la recherche académique intéressés par les informations climatiques, avec un réseau actif de collaborations à mettre en place (on peut citer par exemple le partenariat avec l'ENEA, avec le CSC, … qui augmenteront la portée des travaux).

Pour mettre en place ce groupe, un petit noyau de personnes (5-8) déjà impliquées dans de telles actions serait formé pour bien définir les contours de la nature des actions, et s'élargirait sur la base du volontariat. Il se réunirait tous les 2 mois par une journée dédiée pour le suivi des actions.

Etapes envisagées

Année 1 :

- Constitution d'une « cellule de mobilisation » pour la promotion de l'information climatique, personnes déjà impliquées dans des projets d'application ou d'innovation ;
- Constitution d'un réseau de partenaires extérieurs ;
- Définition et démarrage de quelques développements restant à préciser (logiciels de calcul d'impacts, logiciels de traitement et d'analyse statistique) ;
- Définition d'études ou produits « pilote », en lien avec la KiC Climat.
- Préparation d'une formation sur « les bonnes pratiques pour réaliser une étude d'impact du changement climatique »
- Diffusion de l'information sur des études d'impact déjà menées au sein du labex L-IPSL, notamment grâce aux projets du GIS Climat-Environnement-Société
- Mise en place d'outils collaboratifs (forum, mailing list) pour centraliser les demandes des partenaires extérieurs autour de l'information climatique

Année 2 :

- Extension du réseau de partenaires, de la cellule de mobilisation ;

- Premières réalisations d'étude pilote, de réalisations de jeux de données ;
- Mise en place de la diffusion.

PRODIGUER : Un service de données et d'exploitation des projections climatiques

Le projet PRODIGUER vise à proposer une distribution des données de projections climatiques à l'échelle globale à régionale s'appuyant sur les grands exercices internationaux de CMIP et CORDEX et s'insérant comme un nœud du réseau international de distribution. Le service s'adresse aux communautés de recherche et aux utilisateurs ayant une formation avancée dans le domaine du climat. Le service de données est accompagné d'un service d'exploitation de ces données, via l'accès (par un compte informatique) à des outils de calcul, ce qui en fait un véritable mésocentre de calcul qui s'insère dans la pyramide décrivant l'écosystème de calcul intensif, voir les rapports du CSCI (Comité Stratégique du Calcul Intensif, rapport 2008, p36).

http://www.genci.fr/sites/default/files/CSCI_Rapport2008.pdf

Le projet PRODIGUER a pour but de permettre à l'IPSL de relever pleinement le défi imposé lors de CMIP5 par la gestion de masse de données dans les sciences de l'environnement, et la modélisation du climat en particulier. Les deux axes stratégiques ci-dessous sont tirés de la proposition initiale du projet PRODIGUER au GIS climat et environnement en 2008 :

- « Cet exercice imposé par CMIP5 donne l'occasion à l'IPSL d'intégrer une infrastructure mondiale de gestion de données climatique et de se préparer à l'avenir en acquérant la maîtrise des technologies de grilles de données qui seront nécessaires lors du passage à l'échelle du calcul pétaflopique ».

- « En interne, l'IPSL via une structure informatique multi-site reliant le serveur ClimServ (Palaiseau) au serveur Ciclad (en cours de démarrage sur le site IPSL de l'UPMC) pourra également épauler cette plateforme dédiée à la recherche climatique en explorant les possibilités offertes par les méso-centres de calcul dans le contexte de déploiement d'un portail d'accès et d'analyse de données climatiques de toute nature. »

Un ensemble de jeux de données climatiques élaborés de référence pour les impacts et l'adaptation

Partant des simulations et projections climatiques de CMIP5 et CORDEX, plusieurs jeux de données « élaborées » de référence sont proposés pour permettre à la fois aux projets de recherche sur les impacts et aux études sur l'adaptation de se développer, tant pour la recherche que pour les études applicatives. Ces produits sont issus de projets scientifiques en cours. Ils doivent être rendus plus génériques et documentés pour pouvoir bénéficier d'une large diffusion. Voici les propositions de produits à développer pour les deux années à venir :

- Produit(s) 1 : Un ensemble de simulations historiques et de projections climatiques dé-biaisées et mises sur une grille commune grâce aux méthodes de descente d'échelle statistique développées à l'IPSL (CDFt notamment). Cette transformation des données est souvent faite dans les projets d'application et parfois en doublon, un ensemble de référence

serait indispensable. Par exemple, plusieurs jeux de données comme ceux proposés ont été développés au LMD et au LSCE, et méritent un contrôle de qualité et une mise en forme pour distribution extérieure. A l'échéance de 2 ans, les données débiaisées de surface de quelques paramètres clef (T, P, V, rayonnement, etc) de CMIP5, ENSEMBLES, CORDEX (régions Afrique, Europe, Méditerranée, Amérique du Sud), seront produites et mises à disposition. Idéalement, ce produit pourrait proposer différentes variations, notamment, en fonction des jeux de données utilisés pour la régionalisation, des échelles spatiales et temporelles finales de cette régionalisation ainsi qu'en fonction des méthodes de régionalisation utilisées. En effet, selon les applications, il sera plus ou moins nécessaire d'utiliser des méthodes de débiaisage/régionalisation multi-variées ou mono-variées, voir de distinguer des méthodes capables ou non de gérer les extrêmes. De plus, tous les jeux de données n'ont pas une qualité homogène sur l'ensemble des paramètres. Ainsi, on pourrait orienter l'utilisateur vers des associations projections climatiques/méthodes de régionalisation/jeux de données pour la régionalisation, en fonction des applications, et a minima, bien indiquer les limites des méthodes de régionalisation/jeux de données utilisées.

- Produit 2 : Un ensemble de simulations multi-modèles globales corrigées de biais (par rapport au climat actuel) en 4 dimensions issues de CMIP5, sur une grille commune, pour les variables essentielles permettant de forcer les modèles de climat régionaux aux limites (U, V, T, quelques variables en surface). La correction se fait grâce aux réanalyses (eg ERA-Interim). L'intérêt de corriger les entrées des RCMs est de minimiser les corrections en sortie, pour mieux garantir une cohérence physique entre toutes les variables finalement utilisées. La réunion de novembre 2012 de MISSTERRE-CORDEX a montré l'intérêt pour un tel jeu de données. Cette action, innovante, demandera une validation intensive ainsi que des études plus théoriques.
- Produit 3 : Un ensemble d'indicateurs génériques produits à partir des modèles d'impacts utilisés dans les projets de l'IPSL. Définir des indicateurs du changement climatique pouvant être utilisés dans différents secteurs comme l'agriculture, la sylviculture ou la gestion de l'eau par exemple et dans différentes régions du monde constitue une des actions phare du volet recherche du Labex. Il s'agira de développer une plate-forme permettant la distribution de ces indicateurs.

Il sera important pour ces produits de bien documenter les incertitudes et limitations des jeux de données et des approches utilisées. Cela pourra se faire par exemple par la préparation d'un guide de bonne conduite des utilisateurs de telles données climatiques.

Un jeu multi-modèle de données régionalisées pour le service DRIAS

Il s'agira de fournir à Météo-France, qui pilote le service DRIAS, les données mises en forme (descente d'échelle statistique, correction de biais à l'aide du produit SAFRAN), issues des projets EURO-CORDEX et MED-CORDEX et des nouvelles simulations à haute résolution qui y sont effectuées (10 km environ). Le partage du travail entre Météo-France et l'IPSL est à définir, mais devra inclure le passage sur la grille SAFRAN utilisée par DRIAS et la correction de biais. Ce jeu de données sera disponible au mois 12.

La collecte des projets actuels de valorisation des données et la mise en valeur de

quelques projets phare sur le portail PRODIGUER

A l'instar des études de cas d'IS-ENES, il s'agira de recenser les projets menés à l'IPSL sur le changement climatique et ses impacts. Une première étape pourrait être de permettre l'accès aux ces études d'impact déjà menées, via l'extraction des résultats des simulations sur une région donnée et une période donnée, en se basant sur les scénarios déjà simulés. Une analyse critique de ces études ainsi que des résumés pour les décideurs pourront permettre d'identifier quelques bonnes pratiques qui serviront de base pour les études d'impacts à venir dans le cadre du L-IPSL.

Un ensemble de projections d'impacts du changement climatique

Il s'agira, sur la base des compétences des équipes du L-IPSL, et du travail du WP4, de mettre à disposition les sorties de plusieurs modèles permettant l'étude des impacts du changement climatique et les projets sur l'adaptation. Suite aux développements qui seront faits au sein du volet recherche dédié, il s'agit de fournir à terme (2-4 ans) des produits issus de modèles d'impacts régionaux ou globaux sur les secteurs suivants :

- L'agriculture et la sylviculture (grâce aux développements autour du modèle ORCHIDEE)
- L'eau (également ORCHIDEE, mais aussi les projets développés sur plusieurs bassins versants)
- L'énergie, avec plusieurs projets développés au LSCE et au LMD
- La qualité de l'air et la santé (projets développés au LMD, LISA, LATMOS, LSCE)

Les premières étapes consisteront à établir un réseau de spécialistes IPSL impliqués dans des projets d'impact et désireux de mettre en commun leur expertise. L'objectif est tout d'abord d'organiser le retour d'expérience des études existantes afin d'affiner la démarche. Plusieurs cas de figures sont envisagés consistant soit à isoler des cas pour lesquels des simulations avec des modèles d'impact doivent être réalisées de façon récurrentes ou des cas où le transfert de méthodologies devient effectif (données, analyses, méthodes, ou modèles).

La mise à disposition des sorties des simulations de modèles d'impacts réalisées dans le cadre du projet ISI-MIP auquel participe l'IPSL est également à envisager. En effet, elle permettrait de réunir sur la même plate-forme PRODIGUER les scenarios de changement climatique et ses impacts potentiels.

Des logiciels d'exploitation et d'analyse statistique des données climatiques

Un ensemble de logiciels d'analyse et de transformation de données peut être développé. Par exemple, on peut citer CDFt qui fait actuellement l'objet d'un code sous R, mais qui reste encore mal adapté aux grands ensembles de données comme CMIP5. Un développement spécifique pour ces grands ensembles est à faire, et le LABEX pourra permettre la réalisation de versions testées et validées sur plusieurs plateformes. D'autres exemples sont à définir, par exemple concernant les valeurs extrêmes, les calculs d'indices (et non les indices eux-même), par exemple les indices de sécheresse PDSI, les méthodes d'analogues, la descente d'échelle multi-variée.

Des premiers produits et études prototypes

Ces études, à mener en lien avec les utilisateurs hors domaine académique, restent à bien définir et

cibler car le champ est large. La participation aux travaux de la KiC Climat, notamment via sa plate-forme sur l'adaptation, sera nécessaire, pour bien définir les produits. Ceux-ci seront proposés par la cellule de mobilisation, et une recherche de partenaires et financements nécessaires sera effectuée.

Des exemples de telles études existent dans les laboratoires de l'IPSL. On peut citer notamment :

- le projet ANR SECIF, visant à plusieurs études de cas d'utilisation de données climatiques avec plusieurs industriels
- le projet KiC Climat E3P, visant à développer des produits et jeux de données pour le secteur de l'énergie autour des événements extrêmes
- les projets du LOCEAN sur les rendements agricoles en Afrique de l'Ouest
- les projets GICC

Ressources et organisation

Pour accomplir ces travaux, il faut d'une part soutenir le développement en ingénierie pour la production des données du portail principal PRODIGUER (voir document spécifique PRODIGUER).

Ensuite, une petite cellule « opérationnelle » devra être mise en place pour le développement des données élaborées et produits plus applicatifs. La proposition est qu'à moyen terme elle puisse regrouper :

- La cellule de chercheurs et ingénieurs permanents (7-8 personnes)
- Trois ingénieurs (tâches à répartir entre Saclay et Jussieu), avec des profils différents
- Deux chargés d'affaires « facilitateurs « (1 à Saclay et 1 à Jussieu), dont la mission est le développement des liens avec le monde non-académique, l'organisation de réunions, la rédaction de documents, en lien avec les équipes actuelles
- Une aide de secrétariat

Ces postes n'existent pas et le financement n'existe pas actuellement pour pourvoir tous ces postes en CDD. Un soutien à PRODIGUER est la première priorité, en poste statutaire, et le LABEX apportera en priorité un soutien en attente si nécessaire.

Dans un terme à définir, le LABEX pourra financer un ingénieur « transformation des données », et sans doute un « chargé d'affaires ».

Le LABEX peut apporter à la KiC Climat une partie de son « financement complémentaire », il est donc logique que les ponts se renforcent (par exemple avec un chargé d'affaires commun KiC– LABEX pour aider la cellule de mobilisation). Il est à noter qu'un pré-projet a été défini fin mars 2013.

Les autres postes devront faire l'objet de ressources complémentaires. Ces ressources humaines pourront également provenir de collaborations avec des entreprises qui aideraient au développement des travaux. Enfin, des ressources supplémentaires seront nécessaires pour le fonctionnement : postes de travail, archivage, prestations pour site web ou autres, quelques missions.

A plus long terme, on peut imaginer que cette interface entre la recherche effectuée par l'IPSL et les

utilisateurs (publics et privés) des services climatiques soit hébergée dans une structure indépendante, qui pourrait par exemple être financée par les utilisateurs. Ce modèle aurait l'avantage de permettre à l'IPSL de se concentrer sur son cœur de métier et d'assurer une mutualisation des besoins et une plus grande équité parmi les utilisateurs commerciaux potentiels de services climatiques (en particulier dans le cadre d'activités de consultance). Il convient toutefois d'amorcer ces collaborations à partir d'activités hébergées à l'IPSL comme suggéré ci-dessus.