L – IPSL LABEX

MID AND LONG-TERM ACTION PLAN

JUNE 2012

This document describes the 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 (2012 – 2014).

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 first (the initial?) research projects will be developed,
- a long-term phase (mid 2014 – 2021) where the initial vision will be further developed.

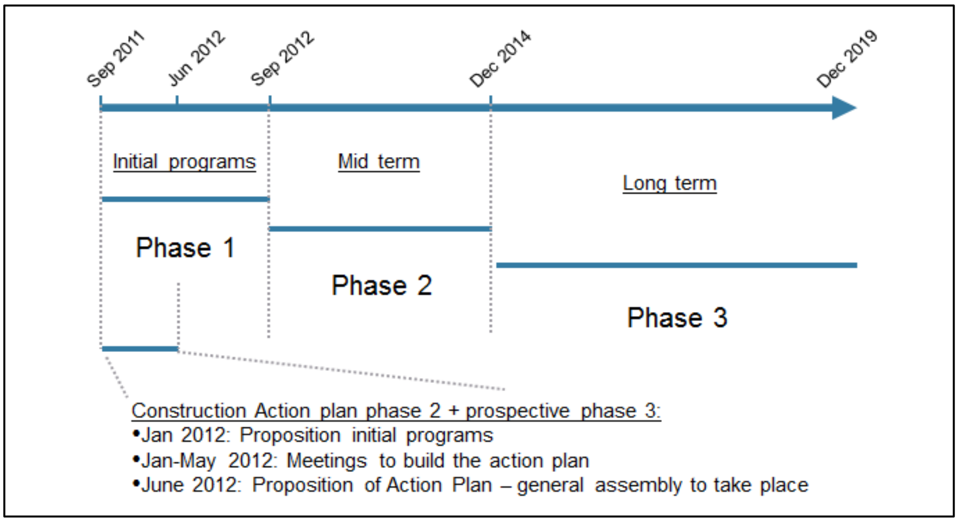


Figure 1: Phases of the LABEX program

1.2 Objectives of this document

The aims of this document are:

- to recall the main long-term issues, objectives of the LABEX program,
- to summarize the actions decided in the initial phase,
- to summarize the 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 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?

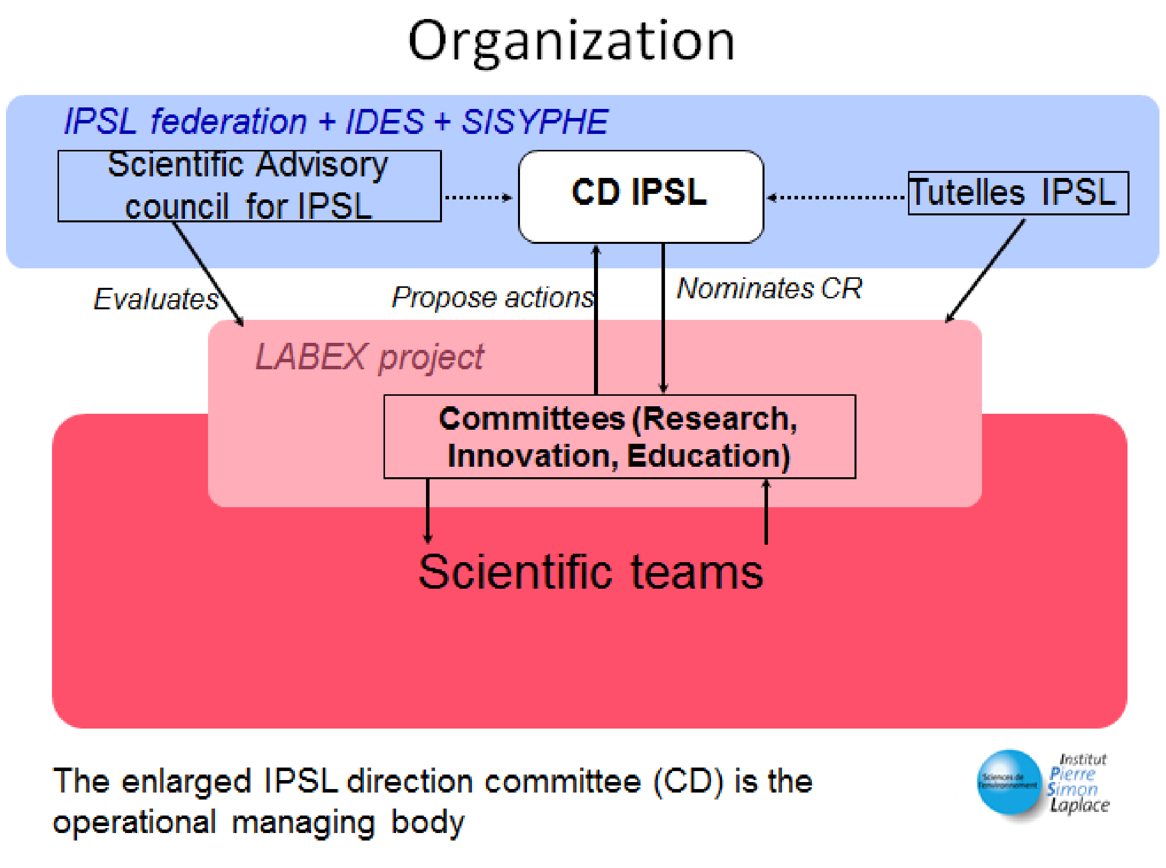
Research is structures in thematic and methodological work packages that address these questions, and rely on existing IPSL infrastructures (modeling, observing strategies) and will benefit from methodological developments for uncertainty estimation.

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 Methodology

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 site meetings for general information about the LABEX program
- a series of open discussion meetings organized by WP leaders in order to identify projects and ideas present in the LABEX community
- a 2-day synthesis committee seminar (19/20 march 2012) to
    - gather all information from the work package meetings
    - identify long-term aims specific to the LABEX program
    - identify the most mature, ready-to-go structuring actions or projects that help address these issues in the midterm (2-3 years)
    - identify important but less mature issues where structuring animation is required before research projects could be launched
- the writing of a mid/long term action plan

The second conclusion was that, for a better efficiency, the scientific program should be constructed progressively and closely followed by the research committee, interacting with the LABEX teams, and not by a series of project calls which would possibly end up in a patchwork of projects.

A third conclusion is that the LABEX funding and actions should be devoted to

- Integrating research or infrastructure actions involving several LABEX teams
- Actions that will favor the combined use of models and observations
- Actions to catalyse new projects and to structure communities
- Leveraging actions
- Research actions that would favor a better transfer of the LABEX expertise and data and training

There is no explicitly specified nature of the expenses that the LABEX should cover but the investment part should remain marginal and the LABEX funding should mainly concern human resources, scientific visitors and functioning (e.g. workshops).

An education committee and an innovation committee have been set up and have defined a strategy and proposed the first LABEX actions (see below).

1.6 Long-term aims

The LABEX project has an important specificity compared to classical projects: it runs over 8 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:

- ***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 ingeneer 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 Mid-term issues (2012-2014)

Research teams of the LABEX are largely participating to the LABEX objectives through ongoing projects. In addition, given the strengths of expertise and strategic considerations, the research committee has identified five key transversal issues for which specific mid-term LABEX focused effort should be put:

- ***Issue 1: The predictable part of decadal changes and the risk of abrupt, nonlinear changes with emphasis on the North Atlantic :***

Efforts to understand and describe internal and forced variability, long-term evolutions and possible episodes of abrupt climate shifts in this area are strategic: (i) because the North-Atlantic climate is characterized by a strong inter-decadal signal whose drivers understanding is essential to climate projections at the horizon of the next few decades (10-30 years), (ii) because AMOC perturbations and ice sheet/ocean interactions are at the heart of major non-linear changes observed in paleo records and (iii) because one needs information to provide scenarios and risks for adaptation to the public, policy makers and industries in Europe and the North-Atlantic ocean. This issue benefits from strong expertise in the LABEX teams both in terms of observations (paleo and recent) and modeling, as well as from expertise in statistics, global and regional modeling of the European climate. An improved understanding of inter-decadal variability should be obtained by better bridging observations and model simulations. As far as abrupt changes are concerned, comprehensive climate models used for future projections are stable and lack the components yielding non-linear responses. Introducing sources of instabilities is an important aspect of issue 1 (i.e. coupling realistic models of ice cap dynamics in IPSL model).

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

Targeted research efforts are needed in order to better quantify and understand the carbon sinks, both in the ocean and 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 (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 developed in ORCHIDEE, bridging the gap between the expertise existing at SISYPHE, LMD and LSCE. 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.

- ***Issue 3 : Changes in the precipitation regimes and water resources :***

Efforts are needed to develop a capacity to predict water resources under climate change. This will require several emphasis in the LABEX mid-term research : (i) to reach a better understanding of the drivers and a better modeling of rainfall regimes, which are currently not well predicted by climate models ; one specific question is how to model precipitation regimes which depend on weather systems lying over a wide range of scales, and how high-resolution regional limited-area or zoom models, necessary to simulate heavy rainfalls, can also cover intermediate scales, also covered by GCMs ; (ii) to develop a capacity, using a downscaling chain of models, and existing observations, to predict river future statistics in river discharges, droughts and floods due to extreme events. Downscaling model chains, either of statistical or dynamical nature, raise many issues and offer many possibilities and properties to be explored, especially regarding the water cycle phenomena. Major efforts will be to bridge across spatial scales, account for model biases, and to combine and evaluate the use of indicators specific to hydrology.

- ***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, can contribute to this aim providing information with which to assess model performance. At the same time identification of pertinent scientific research that can be tackled by groups in L-IPSL will enhance the potential contribution of L-IPSL to the new national effort 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.

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

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.

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.

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

▪ *Work Package 2: 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.** By contrast to that of GHG, aerosol radiative forcing is subject to a larger uncertainty and the L-IPSL will seek to understand aerosols radiative forcing change in the future. The primary mechanisms involved in the spread of climate feedbacks, in particular those due to radiative feedbacks will also be explored. In this context, the fate of other climate parameters and phenomena will also be addressed (e.g. tropical precipitation change, AMOC, ice sheets dynamics,…).

- **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.

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 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). At the moment, the physical and chemical representation of volcanoes in the IPSL model is 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 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 research plan for this action is mature, will require 2 years of postdoc and a workshop can be organised after this initial two year period. Building on a unique combination of in-house modelling and observation expertise and a number of projects (see list), this action will place IPSL at the forefront of this new and exciting research field.

This action is also a contribution to TWP1.

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 to mature into specific integrating action (cf HAMOCC ANR).

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).

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 be decided on the basis of several meetings.

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.

Action 5: Initialisation 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. Beyond ocean initialisation, we will explore sea-ice and land surface initialisation. This action will 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)

EU: SPECS (FP7, 2013-2017), EUCLIPSE (FP7, YYYY-YYYY), COMBINE (FP7, YYYY-YYYY).

▪ *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.

This action needs to be developed and the design of an ensemble of simulation experiments involving several models used at IPSL: regional limited-area and the zoomed version of LMDz. This design will be achieved through preparatory meetings during fall/winter 2012-2013, and will be proposed for funding in 2013. A 1-year post-doc position is currently planned for this work.

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 and the work of a post-doc, in common with WP4 and TWP3.

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 is fostered by the visit of Amato Evan (during initial LABEX phase, see above) and will contribute to Issue #1.

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. Specific processes such as the impacts of aerosols will also be examined. Workshops will also be held to identify and develop cross-cutting research topics. This action will contribute to Issue #4.

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

This task will benefit from the visit of Steve Clifford in the initial LABEX phase, as well as that of Jerome Fast (PNNL) will visit LATMOS and foster collaborations in the field of regional chemical/aerosol modeling and aerosol-cloud interactions.

Links to other projects

On-going FP7, ANR, INSU, IRD projects in West Africa (non exhaustive): AMMA, AMMA-2, FENNEC, RIEPCSA, etc… Contribution to “Chantier Arctique”, possible IPSL lead for national projects (ANR?). 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 ACCESS, ECLIPSE and CLIMSLIP 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.

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.

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

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[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

also be encouraged for documenting poorly-known relationships between hydrology/ecosystems and climate change.

Regular meetings and workshops will be organized to promote Actions 1 and 3, and to coordinate process studies and model developments for better impact assessment. These meetings will mostly be internal to the L-IPSL, but we may also invite French or foreign experts if topical.

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.

▪ *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 and the L-IPSL support will be requested to organize a workshop on the *state-of-the-art* of rapid, Holocene climate variability in october 2012 at University of Paris-Sud (with a co-support from PRES UniverSud-Paris, UP11, IDES and L-IPSL).

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. As for the action 1, discussion and maturation will benefit from the organization of specialized workshops in the second part of 2012.

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.

Because improving chronologies and stratigraphic correlations is a key issue for the three actions listed above, the WP5 will set up quickly (within the upcoming six months) a workshop devoted to presenting and discussing the *State-of-the-Art* in stratigraphy and dating.

WP5 will also seek the L-IPSL support to help organizing the *First Open Science Conference of IPICS (International Partnerships in Ice Core Sciences*. We believe it is important that L-IPSL is identified as a sponsor of this key international conference on Past Climate Variability that will take place in France (Presqu'îles de Giens, October 1-5 2012).

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.

As stated above, the preparation of a detailed timetable including deliverables for these four, mid-term key topics of the L-IPSL WP5 will require the organization of specific workshops before the end of 2012. These workshops will also make it possible to identify and rank one or two key targets requesting a specific financial support from the LABEX. Although further discussion is needed, there seems to be already a general consensus, however, about the importance -for all WP5 main actions-of (i) improving *past hydrological cycle reconstruction and water fluxes*, and (ii) *developing precise, integrated chronologies*.

- To improve our understanding of water isotopes and past hydrologic cycle and improve our ability to provide estimates of water flux disturbances, the WP5 strongly supports the proposition debated within TWP2 to set up a database on water isotopes (ice, marine cores, speleothems,..) and use it for careful data/model comparisons around key periods identified by PMIP3-CMIP5 (the last millennia, the mid-Holocene (6ka) and the Last Glacial Maximum (21ka)). The setting of such a database will likely require hiring a postdoc.

- To improve chronologies and develop accurate stratigraphic frameworks that are necessary to fulfill WP5 objectives, it would be necessary to hire a post-doc in order to work on the development of multi-archive, integrated age models. Final decision about this post-doc position will take place during a specialized workshop (see above), and will require that the decision about ANR MACHRONO is known.

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). On-going data-oriented or modeling projects at the European level or national level (NEEM, EMBRACE, COMBINE,…).

▪ *Transverse Work Package 1: Numerical modelling 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 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".

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).

Action 3: 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.

Links to other projects

National:

- **MissTerre (LEFE/IMAGO, CNRS/INSU)**
- **Dephy (LEFE/IMAGO, CNRS/INSU)**

European

- **COMBINE**
- **EMBRACE**

▪ *Transverse Work Package 2: Data management*

Main objectives and strategy

Observations for monitoring climate changes require long data sets. Available series of observations 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 in collecting simultaneously many different types of data to better understood processes. Finally innovative instruments and methods are required to access new measurements that help to characterize climate changes and constrain models. Preliminary tasks consist then in 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 propose to complement and insure a better coordination with the thematic national data centers like ETHER or ICARE respectively for atmospheric and aerosol composition. 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 measurement and/or paleo-proxies through proxy-forward models.

Contribution to the mid-term key issues

Action 1: 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 too and direct link provided.

Action 2: Water stable isotopes database and working group

The isotope composition of water allows to give information about the history of water (phase change, temperature, convection, precipitation). This is a complex but a useful information for atmospheric, continental and oceanic water for both actual measurements and paleoclimate archive. While the isotopes are already include in LMDz and ORCHIDEE models it will be 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.

The second one consists in forming a specific working group, on water isotope in a first stage, then other isotopes might be included, whose objective will be to accompany 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 elaborate campaigns using Picarro spectrometers and other measurements dedicated to water cycle investigation, in different domains.

Action 3: Statistical data analyses for climate attribution

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 the causes. Sophisticated and robust statistic methods need to be developed. 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.

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 those proposed instruments are different but are using similar expertise. To conduct an optimal development of the future innovative instruments, dedicated workshops are required. Within the LABEX, attention will be paid to GES observations.

Action 5: development and shared use of analytic platforms

Climate change research will benefit from the coordinated use of analytic 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 further develop shared use of this platform within LABEX laboratories, and to coordinate efforts with other instruments in the other laboratories.

Links to other projects

The isotope working group will also 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.

▪ *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.

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.

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.

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.

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.

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.

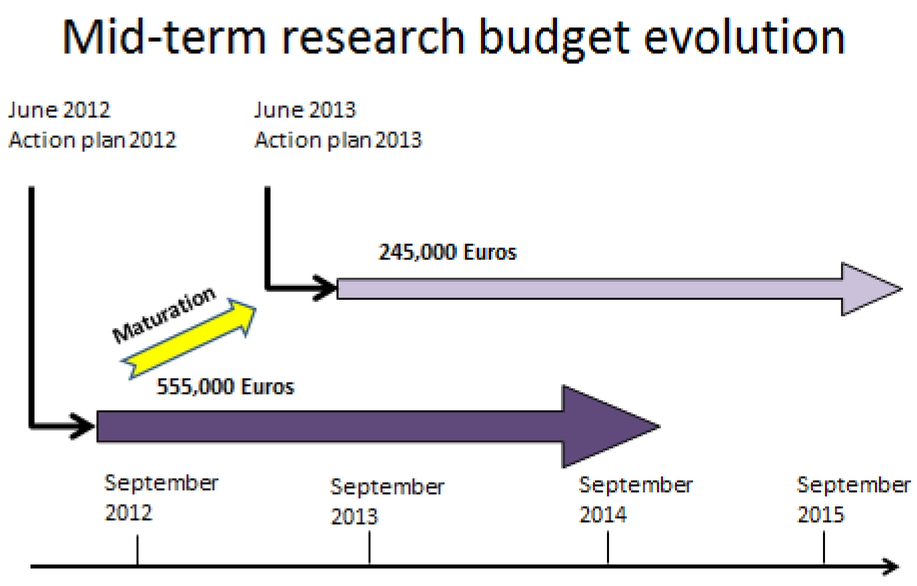
2.4 Research: summary of contribution of Work Packages to the mid-term issues

Contribution of WPs to mid-term issues	Mid-term actions	Issue 1 Decadal variability and changes	Issue 2 Productivity trends, attribution of RF	Issue 3 Precipitation and water resources	Issue 4 Fast changes in Arctic	Issue 5 Indicator factory
WP1 Atmospheric composition	1: interaction of cycles 2: C transfer in arctic rivers 3: RF attribution	 +	++ ++ ++	+ ++	 ++	
WP2 Future climate and Predictability	1: 2: 3: 4:					
WP3 Regional scale	1: intermediate scales 2: regional climate variables 3: reg. land/atm/oc. Interact. 4: processes in the Arctic	 +		++ + +	 ++	+ ++
WP4 Impacts	1 & 2: indicators 3: extrapolation times On-going process studies		+ + +	++ + +	+ + +	++ + +
WP5 Abrupt unpredictable evolutions	1: clim. variab. reconstruction 2: abrupt ch. in warm climate 3: Rapid glacial variability 4: polar caps destatbilization	++ ++ ++ +			+ ++ ++	
TWP1 Numerical modeling	1: higher resolution 2: cycles integration 3: Streched version 4: Tools/distribution	+	 ++	++ +	 ++	++ ++
TWP2 Observations and data distribution	1: arctic data portal 2: isotope data base 3: statistics, attribution 4: lidar strategy 5: Analytic platforms	 ++ ++	+ + +	 ++ ++ +	++	+ +
TWP3 Uncertainties	1: multimodel analysis 2: key diagnostics / evaluation 3: best practices 4: uncertainties in indicators 5: sources of uncertainties					++ ++ ++ ++

Summarized contribution of WPs to the mid-term issues
(++ : strong involvement; + : weak involvement)

2.5 Research: Provisional Budget for the mid term

The LABEX budget will be decided 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 includes 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, to be re-discussed.

A yearly budget [2012, 2013, 2014] will be established based on detailed numbers, given time of recruitments and workshops in particular.

The table below summarizes the proposed funding for mature actions and envisaged funding otherwise to be re-discussed in 2013, for the mid-term research action plan. Actions proposed for funding (yellow lines) are distinguished.

Proposed funding and laboratories involved (in alphabetic order)	Dates / schedule	WPs (leading WP boldfaced)	Mid-term Issue	Proposed budget (Keuros)	Envisaged budget (to be proposed 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. Required funding depends on ANR MACHRONO, but would complete even if accepted IDES/LOCEAN/LSCE	Mid 2013 --> Mid 2014	**WP5**	**Issue 1**	**45**	
2yr post-doc (or 3yr PhD) to study the role of volcanism in the last millenium LATMOS/LMD/LOCEAN/LSCE	2013 and 2014	**WP2-WP5**	**Issue 1**	**90**	
1 Year post-doc to develop the attribution of radiative forcing to changes in productivity LOCEAN/LMD/LSCE	2013	**WP1-WP2**	**Issue 2**		**90**
Invitation of an expert on cycles interactions	2013	**WP1**	**Issue 2**	**15**	
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 post-doc to address the issue of the regional modeling of the intermediate scale Application to rainfall regimes in West Africa and Europe - labs TBD	Mid 2013 --> Mid 2014	**WP3**	**Issue 3**		**45**
1 Year Engineer to develop the Arctic data portal ALL	?	**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 for the testing of new configurations IPSL	2013 and 2014	**TWP1**	**Issue 5**	**90**	
1 year post-doc Return of experience CMIP5/CORDEX and publication of model results - labs TBD	End 2013 - End 2014	**TWP3**	**Issue 5**		**50**
Workshops	Sep 2012 - Aug 2013	**All**	**All**	**30**	**30**
Other actions to be decided and supported in 2013					**30**
Total				**555**	**245**

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. One task is to have a precise inventory of all instrumentations .
- 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 the first years, L-IPSL activities will be 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.
- Lidars : Procedures / Guideline for the different cases of industrial partnership will be written: leosphere, Gordian strato, Cimel;
- Another mature field of instrumentation which could be transferred to industry or develop innovative instrumentation will be chosen;
- Coordination of people in charge of valorization in the different L-IPSL laboratories will be implemented;
- Link with SATT, inquiry of needs of industrial partners will be done.

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.

Over the first few years**, L-IPSL will develop a climate service strategy, 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**. The strategy relies on three mandatory components of a climate service:

- Climate projection data distribution, including uncertainties
- Access to expertise
- Development of prototype projects with users

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.

In parallel to the technical development of the portals, an **indicator factory methodology** will be implemented: from the works of L-IPSL WPs, and specifically WP3 WP4 and TWP3, indicators developed in ongoing interdisciplinary impact projects (including from DRIAS users committee) will be defined with the concerned communities, evaluated and set up in data production.

The involvement of researchers, ingeneers 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. 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 Indicative budget

- An engineer position to help the organization of the expertise and transfer tasks above described
- The development of the services will require to hire a 2-year project manager and may benefit from the visit of scientists with recognized expertise in the field of climate services.
- Provision of 40/50K€ per year to help innovative development.

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. This general objective is organized in three tasks, which will be animated and coordinated by the education committee of L-IPSL, formed by one professor or assistant professor per partner of the L-IPSL:

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

In phase with the *plans quinquennaux* of the universities, the education committee will propose the development of a joint knowledge base and skills that all graduate students studying climate should have. A label will be 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 practical approach of climate sciences will also be proposed to undergraduate students in order to make formations and job opportunities around climate issues more visible and attractive.

The objective of this task is to have the same implementation plan in the *plans quinquennaux* of the different universities partner of L-IPSL. This approach will be an opportunity to progress towards an 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. Networking will be done to create a series of specific partnership with some foreign universities and schools. Possibility to develop in parallel an offer of master in English will also be discussed by the committee. A Web platform presenting the education offer, hosting a resource centre for teachers about climate sciences and guiding students towards the best pathways based on their interests and their targeted jobs and skills will be developed in partnership with PRES UniverSud-Paris and with the support of a contractual assistant hired by L-IPSL. This task (and others) will benefit from the deployment of consistent e-communication rooms, easily linking L-IPSL sites with videoconferencing systems. A second set of sites will be equipped or updated in 2012-13 (first set done in 2011-12).

- ***Task 2: 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 proposed or advertised to complement existing offer at a national level.

Training for trainers and influencers will be developed. Multiday sessions for teachers, journalists, policymakers, engineers, … will be designed, developed, and proposed, based on the work packages of L-IPSL and based on ongoing projects on data analyses and climate sciences. The expected effect of leverage will be consolidated by proposing short written synthesis and self-supporting teaching contents for the main issues related to the research performed within L-IPSL. The contents will be proposed to different catalogues of professional training and teaching teams will be organized to perform the sessions using the same education content. A specific offer will be dedicated to PhD students, complementing if necessary what is proposed within the Climate KIC and doctoral schools.

- ***Task 3: Professional insertion***

The objective of this task is to create closer links with the potential employers of the students of L-IPSL including academic and non-academic ones. The promotion of our training sessions 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.

The success of these three 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, 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.

4.2 Mid-term actions

The education committee, with the support of the education assistant 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
- 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.

4.3 Indicative budget

The education budget is currently being discussed. An indicative budget will be of 150,000 euros/year.

5. Innovation and Education budgets for the initial phase (2011-2012)

	Proposition	Estimate budget (K€)
COMMON Innovative transfert expertise and Formation	Data storage - Upgrade of networks	60
Formation	Videoconference material	65
	support to conference - web...	30
Innovative and Transfer	Support to ESPRI - Funding of X month engeneer	50
	Support to Lidar projects - Industrial feasability study	35
	Ret T lidar H20	65
		305