	Programme VMCS	Réservé à l'organisme gestionnaire du programme N° de dossier : ANR-08-VMCS-00 Date de révision :
	Document de soumission B	**Edition 2008**

Acronyme	**SCAMPEI**
Titre du projet *(en français)*	Scénarios Climatiques Adaptés aux zones de Montagne: Phénomènes extrêmes, Enneigement et Incertitudes
Proposal title *(en anglais)*	Climate Scenarios for Mountain Areas: Extreme Events, Snow Cover and Uncertainties

Contents

1 *Technical and scientific description of the proposal*

1.1 *Rationale*

This project addresses some aspects of vulnerability of French mountain areas with respect to possible climate changes in the 21st century due to increasing greenhouse gas concentration. We will concentrate on snow cover, intense precipitation, heat waves, strong winds, dry spells and debris flows. The scientific approach is based on very high resolution (12 km) numerical modeling of the atmosphere/soil system over France under several IPCC hypotheses as well as on meso-scale statistical downscaling (8 km) of the surface atmospheric fields. Both dynamical and statistical downscaling will be developed to derive estimates of snow amount over mountain areas (Alps, Pyrenees, Massif Central, Vosges, Jura and Corsica) including surface elevation effects within each 8 km box. Our view is that this mixed approach (dynamical and statistical) is the optimal one as it relies upon the **complementarity of the two downscaling strategies**. This is particularly true for the uncertainty problem. A strong emphasis will be set on **uncertainty estimation** by considering explicitly the various sources of uncertainty. The emission scenario uncertainty will be estimated within the dynamical downscaling approach by using three concentration scenarios and three high resolution regional climate models. The structural uncertainty (that linked to differences in the model representation of key processes) will be analyzed and quantified with an original statistical technique, applied to the quasi-complete set of IPCC-AR4 simulations (the so-called CMIP3 -coupled model intercomparison project 3- dataset). Over the French Alps, a more detailed snow model will be used to refine the response of the snow pack and its stability to climate change. A statistical model will be used on the same region to evaluate the risk of debris flows.

1.2 *Background, objective, issues and hypothesis*

Motivation

Climate change has become one of the foremost issues on the political and scientific agenda. Major European climate changes have already occurred and will likely continue during the 21st century (AR4, 4th assessment report, IPCC 2007). The intensity and direction of changes, however, will be regionally and seasonally specific.

Mountain areas are among those regions where the most significant impacts of climate change are expected. Indeed, mountain regions have already experienced a steeper temperature rise than the global average in the 20th century (Beniston 2003). Furthermore, severe recent meteorological (e.g. 1999 Christmas storms) or climatic (e.g. 2003 hot and dry summer) events have stressed the vulnerability of the mountain regions to these specific extremes. Even more alarming, however, is that **mountain areas are highly sensitive to any kind of change** (e.g. EEA 2004). The accelerating drainage of the already limited water storage of glaciers is increasing and threatens the sustainability of water supply in increasingly dry summers (Schär et al. 2004). The rapid retreat and increasing collapse of mountain glaciers and the changes of snow cover and duration will significantly affect the hydrological regimes and the coincidence of the loss of the great majority of the ice mass with increasingly hot and dry summers could have a dramatic impact on society in many mountain regions in the next decades. Changing temperature and precipitation patterns may durably alter the magnitude and frequency of floods, avalanches, rockfalls, landslides, and debris flows (IPCC 2007). Such impacts are expected from future climate projections but some of them are also already observed with increasing rate and magnitude. The impacts of these changes will be far-reaching, influencing not only the inhabitants of mountain regions but also tourists and transiting traffic. They can also involve downstream effects for large parts of basin-catchments, especially concerning water availability in warm and dry summers as the flows of major European rivers fed by melting snow and glaciers from mountain regions decrease (Lehner et al. 2006).

Observed climatological data give evidence that temperature has increased in the 20th century in particular over France (by about 1°C) and measurements at Col de Porte (French Alps, Martin et Etchevers, 2005) indicate a negative trend in snow amount since the 1970s. This site was chosen by the ONERC (observatoire national sur les effets du réchauffement climatique) as an indicator of climate change : www.environnement.gouv.fr/-ONERC-.html. In particular, winters 1988/89, 1990/91 and 2001/2002 have been marked by a deficit in snow cover over all French mountains. On the other hand February 1999 experienced heavy snowfall and avalanches in the North of the Alps.

State of the art

Owing to the complexity of mountain terrain, projections about climate change impacts are typically performed at coarse regional scale (e.g. Giorgi et al. 2004) which differs substantially from the landscape scale (Beniston 2006) and from scales decisive for stakeholders. Most 21st century climate projections up to recently generally relied on climate scenarios from coarse resolution General Circulation Models (GCMs, e.g. Giorgi and Bi, 2005). This is still the case for all the impact studies based on the climate scenarios performed in the framework of the IPCC AR4. Previous studies with these models can only resolve scales on the order of at best 200-150 km which is largely insufficient for the vast majority of impact models as they usually require climate data at a much finer resolution (often down to a few km or even less). In mountainous regions in particular, their resolution is particularly poor compared to terrain characteristics and a much higher resolution (on the order of a few km) is required to resolve the slopes and elevations of the important mountain ranges. Therefore, a large number of **dynamical and statistical downscaling** methods have been developed over the years in order to add value to the coarse resolution GCM results.

The first approach (dynamical downscaling) wants to exploit the full potential of the Regional Climate Model (RCM) simulations performed within the modeling framework (Giorgi, 1990). Regional models are known to give a deeper insight into the dynamics and the physics in high complex terrain. At the European level, an intense cooperative regional climate modeling activity started in the early 1990s. The RCMs (either limited area model or global variable resolution model) typically covered Europe at a 50 km horizontal resolution. This activity culminated with the PRUDENCE EU-FP5 project (Christensen and Christensen, 2007) with more than ten RCM focusing on Europe at the end of the 21st century. Ongoing projects (EU-FP6) which attempt to go further PRUDENCE are ENSEMBLES and CECILIA/CLAVIER.

However, even the current generation of RCMs may not have the resolution needed to adequately represent the synoptic environment and the soil-atmosphere interactions in mountainous regions. Typical RCM meshes (25-50 km) cannot resolve important characteristics of the circulation patterns and, particularly in complex topography areas, vertical wind velocities which affect the thermal and moisture distribution (including precipitation patterns). This implies that bias correction techniques need to be applied to RCM outputs before being used in impact assessment studies. Using regional modeling and bias correction techniques, the national IMFREX project (of the GICC program, Gestion et Impacts du Changement Climatique, ministry of environment) has performed an exhaustive study of a selected set of extreme event indices and an open daily database for France at 50 km resolution for the period 2071-2100 (Déqué, 2007). More recently, other projects (MESR-ACI funding :DISCENDO, CYPRIM, and ANR: CLIMATOR, MEDUP) have addressed specific aspects of climate impacts over France, including an examination of the first half of the 21st century. With regard to the dynamical downscaling, all these projects rely on numerical simulations at 50 km resolution.

The second approach (statistical downscaling) relies upon a transfer function which links large-scale climate predictors from climate models and high-resolution observed datasets for the variables of interest (like temperature and precipitation). A wide range of statistical downscaling methods have been developed in previous EU-FP projects such as STARDEX as well as in the current ENSEMBLES project. These methods include various analogue methods, improved regression methods conditioned by circulation, neural network methods including self-organizing maps, conditional stochastic weather generators and weather regime approaches. They all rely on the existence of multivariate observed datasets with high spatial and time density as well as homogeneity properties. They assume a stationary relationship between the predictors and the predicted variables. They must also rely on predictors that can capture the effects of climate change and not just of climate variability. As far as French mountain areas are concerned, impact studies have used statistical downscaling of the best possible resolution. In Martin et al. (1997) a detailed description of the snow cover in the French Alps was downscaled from coarse resolution GCMs. In Jomelli et al. (2007a) debris flow probability was estimated by regression from 50 km resolution IMFREX scenarios.

Issues

Our main goal is to further improve and complete the French mountain areas assessment from previous studies by the use of a joint approach based on dynamical downscaling using 12 km resolution RCMs and statistical downscaling using the SAFRAN 8 km meso-scale analysis (Quintana-Segui et al., 2008) as the observed dataset needed to build the transfer function. Mountain local climate is the product of complex multi-scale interactions depending on atmospheric stratification and moisture content, surface energy balance and topography combined with the synoptic and meso-scale forcing. High-resolution (1-3 km), non-hydrostatic, full-physics, state-of-the-art meso-scale models are currently the best tools to study and represent the high spatial and time variability of the mountain ranges circulation and climate as well as the severe weather events occurring in these areas (heavy precipitation events and related flooding episodes, strong wind events, intense drought). However 2 km resolution non-hydrostatic 30-year simulations over France will not be technically affordable before several years (at least ten years if we extrapolate computer progress of the last 20 years). The choice of 12 km is thus a good compromise, based on very recent results. In particular, Déqué and Somot (2008) as well as preliminary results of the above-mentioned CECILIA EU-FP6 project indicate that the French RCM ALADIN at 12 km resolution largely improves the stationary features of the precipitation field in the range 12-50 km. The weather type-based statistical method will be adapted: the weather types were originally selected to represent rainfall regimes over whole France and a specific treatment may be necessary to represent the circulation patterns relevant for the mountain areas. It then will be used to produce climate scenarios for mountain areas from the IPCC AR4 (the CMIP3 database) as well as from the set of RCM simulations realized within the project

This SCAMPEI project will explore some vulnerable aspects of French mountains (local winter snow distribution as a function of altitude, intense precipitation, heat waves, strong winds and dry spells) with new simulations and new downscaling techniques. Our basic hypothesis is that climate change will be highly contrasted in these regions and that higher resolution atmospheric forcing can bring valuable information to impact models, and therefore to adaptation strategies. On the other hand we need to check to which extent this increased accuracy makes sense. The part of the project devoted to uncertainty evaluation will be a significant issue (see next section).

1.3 *Specific aims, highlight of the originality and novelty of the project*

The scientific objective of the project is to contribute to the study of the vulnerability of mountain areas of France to climate change by evaluating the time evolution of a certain number of local indices of detrimental phenomena such as lack of winter snow cover or intense precipitation. In this project, mountain areas are defined as the metropolitan part of the country where the mean elevation in 8kmx8km boxes is above 600 m which corresponds to 17% of the territory. In the case of the French Alps a further exploration at higher soil resolution will be conducted. Up to some extent, this project bears some resemblance with the GICC-IMFREX project (2002-2004) which attempted to describe the climate change over France in terms of extreme indices and impacts on a panel of societal activities. The innovative aspects are:

- the use of higher horizontal resolution (12 km instead of 60 km) with improved physical parameterizations (in particular for strong surface winds)
- the availability of the first half of the 21st century (IMFREX was restricted to the end of the century)
- the more extensive exploration of uncertainties with the use of A2, A1B and B1 IPCC-scenarios and the downscaling of most IPCC-AR4 simulations (IMFREX was restricted to two RCMs and A2 scenario)

On the other hand, we will concentrate on the mountain part of France and we will not address the question of the observed 20th century (for which IMFREX conclusions about all-season warming and winter precipitation increase in station data from 1900 through 1999 are still valid). Other innovative aspects are the use of two state of the art snow schemes:

- ISBA-ES is a low cost three layer snow model (Boone et Etchevers, 2001), which simulates the main features of the snow cover. It has been validated against observations and by comparison with the detailed snow model CROCUS and participated in the intercomparison projet SnowMIP1 (Etchevers et al., 2003). It will be used to simulate the snow cover over all mountains (Alps, Pyrenees, Massif Central, Jura, Vosges and Corsica) at a resolution of 8 km. Note that the RCMs have their own snow scheme coupled at each time step.
- CROCUS (Brun et al., 1989, 1992) is a more comprehensive model that will be run over the Alps, driven by downscaled fluxes of some of the RCM simulations. The CROCUS model will be run on several slopes of mountainous “massifs” (non-regular grid), which can be considered as climatically homogenous. This method allows to take into account the effects of elevation (with a vertical resolution of 300 m), slope and aspect. Moreover, a stability analysis of simulated snow profiles will be performed with the MEPRA model.

The availability of the new high resolution SAFRAN climatology enables to validate the added value of higher resolution RCM and to build refined downscaling techniques based on weather regimes. We will compare the downscaling and statistical downscaling results with the aim to clearly identify the pros and cons of each approach in the case of mountain ranges impact assessment studies. For the first time, we will have a coherent suite of modeling tools from GCMs to 12 km-RCMs. Statistical downscaling can be applied to each of the suite element and compared to the bias corrected modeling results. We will also provide estimates of the various sources of uncertainty, namely emission scenarios, model uncertainty (both GCM and RCM) and investigate the associated physical mechanisms. The idea here is to identify the links between the spread in simulated future changes and the representation of a physical process or variability in the current climate (Boé et Terray 2008). The ability of the various global and regional models to simulate these processes in the current climate will be assessed in order to select the subset of global and/or regional scenarios which can then be used for specific impact assessment studies.

One of the success of the IMFREX project is its freely available database on which researchers, students, teachers, impact evaluators can download daily model grid point values for climate variables. In addition to the scientific results and the related publications of SCAMPEI, we propose to open at the end of the project a distribution site which would offer to the public an updated (higher resolution, wider period of the 21st century, more scenarios) version of the already 4-year old IMFREX site. This site will also offer decadal syntheses of seasonal climate characteristics including extreme event indices based on international STARDEX convention for temperature and precipitation and strong wind and snow cover indices (to be defined in the project).

1.4 *Project context*

After 15 years during which the RCM community has been working at 50 km resolution, the recent projects start to explore the benefits of higher resolution. In ENSEMBLES, RCM scenarios are run at 25 km resolution. However, the lateral boundary conditions are provided by IPCC-AR4 simulations with 200-300 km resolution.

As the consequence, the RCM domain must be large to limit error contamination (in ENSEMBLES the corners of the common domain are Greenland and Red Sea). The ENSEMBLES RCM simulations are very expensive and his approach is replaced by double nesting in the more recent EU projects CECILIA and CLAVIER. Two of the three RCM partners of SCAMPEI (GAME and LMD) are also workpackage coordinators in CECILIA and CLAVIER respectively. The double nesting technique consists of using a variable resolution global atmosphere model with 50 km resolution over Europe to drive a higher resolution RCM. The variable resolution global model is in turn driven by the sea surface temperature of an IPCC-AR4 GCM. CECILIA and CLAVIER are targeted to central and eastern Europe (common domain over Hungary), so there is room for a French national project exploring the same RCM strategy over France.

The treatment of the uncertainty issue has also seen many recent developments (Tebaldi et al. 2005, Rowell 2006, Rowell and Jones 2006, Giorgi 2005). In particular the FP5 DEMETER project has shown convincingly that a multi-model combination could provide a significant improvement over single model ensemble forecasts in the context of seasonal forecasts. Also, the PRUDENCE project has been quantifying some of the uncertainties involved in climate change projections using regional climate models. The ENSEMBLES project is pursuing these efforts by enlarging the GCM-RCM matrix. In contrast with PRUDENCE (where this matrix was very sparse), several RCMs are driven by different GCMs, allowing for a better estimate estimate of the projection spread due to both the RCM and its driver. One of the goals of ENSEMBLES is to produce probabilistic regional scale climate change scenarios within the context of this multi-model ensemble system. Nevertheless and as stated above, statistical downscaling is still currently the only suitable approach to assess the scatter associated to global coupled models uncertainty when looking at regional impact assessments. Recently, an original statistical downscaling approach based on weather types has been applied to the full suite of IPCC SRES-A1B scenarios to derive hydrological changes over France (including stream flows for the major river catchments and snow water equivalent for the mountain ranges) for the 2045-2065 period (Boé et al. 2006, Boé et al. 2007). For instance, it has been estimated that the winter snow water content in the Pyrenees will decrease by 50 ± 10% in 2050 for the elevations between 1000 and 2000m and 30 ± 10% between 2000 and 2500m (Boé 2007).

The SCAMPEI project covers several axes of the VMCS call: evaluation of uncertainties, production of indices to help adaptation strategies, sensitivity to extreme events. The expected climate change will affect the whole country, but its mountain part is more sensitive to some aspects, for example:

- reduction of winter snow cover decreases the “white gold” income and the natural water storage by mountainous areas
- intense precipitation events produce more dramatic flash floods
- long dry spell favor hard to fight forest fires
- winter warming (frost/defrost cycles) increases the risk of debris flows
- warmer temperatures may affect the snow pack stability

Many variables, including snow cover, will be calculated for any point of France at 8 km resolution, but the analyses will focus on the six French mountain areas, with more specific studies over the Alps.

1.5 *Work plan (including preliminary data, work packages and deliverables)*

The work-program is divided into seven tasks which are performed each by one or several partners. The numerical simulations by high resolution RCMs are produced in Task 1. Existing simulations (IPCC) and simulations from Task 1 will be downscaled to a common 8 km grid in Task 2, in order to feed the other tasks with homogeneous material. Task 3 consists of preparing a public database covering France at daily and 8 km resolution to enable results from SCAMPEI to feed further projects or studies. This database will contain mainly results from Task 2, but also from the next tasks. In Task 4 snow cover is calculated for all French mountains at several elevations and at high resolution (8 km). In Task 5 results from Task 4 are refined over the French Alps with a comprehensive snow pack model. In Task 6, the probability of debris flows in the French Alps is derived from the results of Task 2 with a statistical scheme. Last but not least, Task 7 resumes the results of the other tasks in the perspective of uncertainty assessment.

1.5.1 *Task 1: Dynamical downscaling*

Statistical downscaling has an important advantage over dynamical downscaling in that it is computation-ally efficient and allows the consideration of a large set of climate scenarios. Over the 50-year time hori-zon, the variation in projected change is far greater among the various models than among emissions scenarios. Therefore, to fully account for this uncertainty, statistical downscaling of the CMIP3 multi-model ensemble is the most appropriate approach. However, dynamical downscaling using continuously improving RCMs is a very promising tool with several potential advantages over statistical methods as discussed extensively in the literature (Giorgi and Mearns 1999). The foremost reason is certainly the ability to simulate changes in physical processes which are beyond the observed range of variability for the instrumental period (50 to 100 years at most). In particular, changes in regional climate and weather will likely depend upon feedbacks involving orographic effects. Figure 1 shows the surface elevation seen by a model at different horizontal resolutions: 280 km (typical GCM of CMIP3), 50 km (typical RCM of PRUDENCE) and 12 km (as proposed in SCAMPEI).

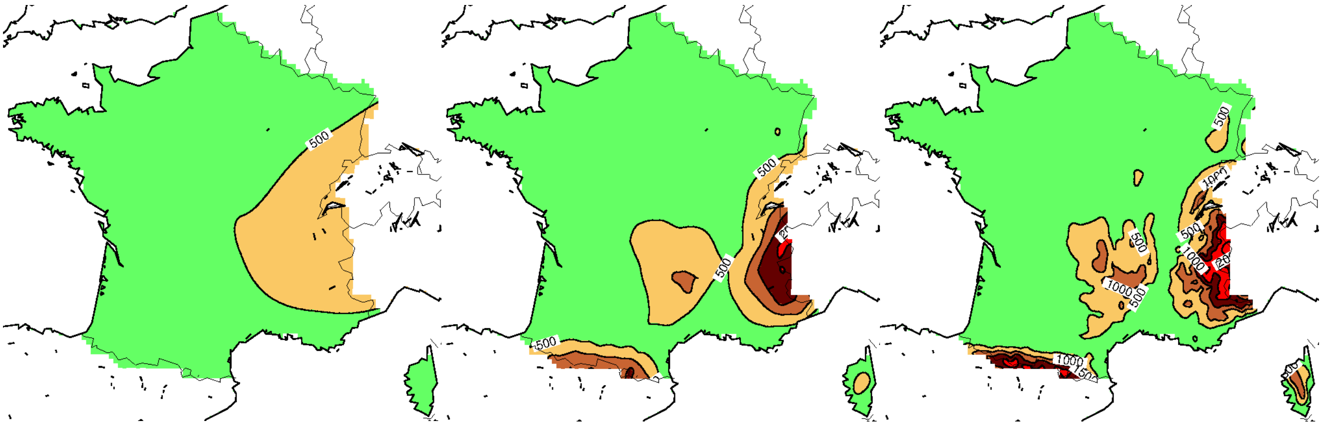


Figure 1: Surface elevation over France used by models at different horizontal resolutions; from the left to the right: 280km, 50 km and 12 km; contour interval 500 m.

In SCAMPEI, the dynamical downscaling will be based on three 30-year simulations: 1961-1990 (reference), 2021-2050 (near future), 2071-2100 (end of century). Near future is necessary for adaptation strategies. End of century allows a better signal to noise extraction and comparison with previous projects (PRUDENCE, IMFREX). End of century may be also necessary for mitigation strategies, as some impacts may be not significant during the first half of the century, due to climate natural variability. The simulations will be based on A1B SRES concentration of greenhouse gases and sulphate aerosols. One of the models will explore the role of the concentration scenario by running the A2 (higher concentration) and B1 (lower concentration) scenarios. The impact of the choice of the concentration scenario is essentially expected in the end of century experiments.

Three French RCMs will be used in the project: ALADIN, LMDZ and MAR. They will be run on a domain covering France at 12 km resolution. Such a resolution is the finest for which one can use the same physical hypothesis as in the GCMs: convection is considered as the mean statistical effect of many convective clouds.

ALADIN (Aire Limitée, Adaptation Dynamique pour la coopération Internationale) has been designed in the early 1990s as a limited area model derived from the global model ARPEGE/IFS for short-range forecasting (Bubnova et al. 1995). A wide consortium in Europe and around the Mediterranean Sea uses a version of ALADIN on national domains at horizontal resolutions close to 12 km. Since the ENSEMBLES European project, a climate version of ALADIN has been derived (Radu et al., 2008). This version uses the same physical parameterizations as the GCM ARPEGE-climate. ALADIN-climate has been validated at 50 and 25 km resolution on a domain covering Europe. The driving simulation for ALADIN in SCAMPEI will be the same as in CECILIA European project. It consists of a global ARPEGE-climate simulation with variable resolution (50 km over France) driven by sea surface temperature (SST) from the IPCC-AR4 contribution of GAME with ARPEGE-climate coupled to an ocean model. As SST bias is subtracted, the climate of ARPEGE over France is more satisfactory than in the coupled simulation in the reference run. ALADIN will be run with the 3 greenhouse gas scenarios (A1B, A2 and B1).

LMDZ is the atmospheric GCM developed at LMD and used in many climate modeling studies. A regional version of the LMDZ, which exploits the zoom possibility of the model, will be used in the current project. Nested into a weak-zoom or zoom-less version of LMDZ, the regional version of LMDZ can be run in the same manner as a classical limited-area model. The model physical parameterizations remain unchanged compared to the driving GCM. In such a way, the physical consistency between the global scenario and the regional scenario is in general higher than other regionalization procedures. LMDZ has been extensively used to accompany the field campaign in Africa in the framework of AMMA EU-project. With a spatial resolution ranging from 30 to 60 km, LMDZ is currently used to study climate change impacts in South-east Asia, in

South America (EU-project CLARIS), Central and eastern Europe (EU-project CLAVIER), and in the Mediterranean basin (EU-project CIRCE). In the current project, LMDZ will be used for the first time with a spatial resolution of 12 km to cover the French national territory. The strategy will be the same as that used with ALADIN, that is, a double nesting approach is proposed to include the LMDZ GCM, a weak-zoom LMDZ over Europe and a strong-zoom LMDZ over France. Concerning the SST boundary-conditions, it is proposed to use the IPCC-AR4 contributions from the two French institutes, IPSL and CNRM, which can provide an assessment on the uncertainty related to global models.

LGGE will use the RCM MAR (modèle atmosphérique régional). MAR has been designed to simulate the surface mass balance of the Antarctic and Greenland ice sheets (Gallée et al., 2005, Fettweis et al., 2007). It is adapted to simulations of the climate of cold regions at a very fine resolution. This is the reason why it contains detailed parameterizations of several physical processes. Atmospheric dynamics are simulated using a primitive equations hydrostatic atmospheric model. Surface processes are simulated using a detailed snow model coupled to a surface vegetation atmosphere transfer scheme. The snow sub-model is very similar to CROCUS model and includes blowing snow process (Gallée et al., 2001). Bulk cloud microphysics are described in conservation equations for water vapor, cloud ice crystals (concentration and number), cloud dropplets, snow and rain.

MAR can be currently driven by ECMWF analyses or nested into LMDZ. In SCAMPEI, it will be driven by the same simulation as LMDZ at high resolution.

MAR may also be used in conjunction with a wind gust model (Brasseur et al., 2002) and with a precipitation disaggregation model (Brasseur et al., 2001). The latter describes conservation of heat and water vapor at the kilometric resolution. It is further developed in the framework of a thesis which will include a surface energy balance in it, and finally couple it to MAR.

The risk of failure with ALADIN is negligible, because a preliminary simulation 1961-1990 with the SCAMPEI version driven by ECMWF reanalyses has been successful (Déqué and Somot, 2008). In the case of LMDZ and MAR, we have some guarantee, since the models have been run successfully at 50 km resolution over domains larger than France. In case of unexpected bad surprise, the solution would be to apply the statistical downscaling to 50 km resolution runs over the France domain.

	ALADIN	LMDZ	MAR
1961-1990	reference	reference	reference
2021-2050	A1B, A2, B1	A1B IPSL-SST, A1B CNRM-SST	A1B
2071-2100	A1B, A2, B1	A1B IPSL-SST, A1B CNRM-SST	A1B

Summary of the RCM simulations of the project

Deliverables

D1.1 seven 30-year simulations with ALADIN (M12 P1)

D1.2 five 30-year simulations with LMDZ (M24 P2)

D1.3 three 30-year simulations with MAR (M24 P5)

1.5.2 *Task 2: Statistical downscaling*

Statistical downscaling is based on the view that regional climate is conditioned mainly by two factors: the large-scale circulation (LSC) which is reasonably well resolved by global climate models, and small-scale features like land-use, topography, land-sea contrast that are not adequately described in the models (von Storch, 1995, 1999). Following this approach, an empirical relationship linking large-scale information (or predictors) and local variables (or predictands) is first established for current climate and then applied to derive the regional climate scenario from the LSC simulated by a low resolution model. The task main objective is to use a recently developed statistical downscaling model (SDM) based on weather types to generate future climate scenarios for the French mountain areas at high spatial resolution (8 km).

The observed dataset is the meso-scale analysis SAFRAN which covers France at 8 km resolution. This analysis was first developed by Durand et al. (1993) over the Alps in the framework of avalanche forecasting (Durand et al., 1999). It is very adapted to mountain area as it take into account altitudinal effects and sharp meteorological gradient occurring in mountainous areas. This is a guaranty to have very reliable mesoscale analysis for this project.

The SDM is described in detail in Boé et al. (2006) and Boé (2007). This SDM is suitable for the downscaling of several spatially distributed variables at the daily or hourly time step. It is mainly based on weather typing. Originally, the SDM used two variables as predictors: a LSC variable (such as the 500 hPa geopotential height - Z500- or the mean sea level pressure –MSLP-) and the air surface temperature (used to define a temperature index averaged over Europe). Other predictors, such as a vorticity index, can be used as additional predictors to fulfill additional requirements for specific studies (the vorticity index is useful to catch within-type dynamical variability, Jacobeit et al., 2003). The SDM algorithm starts from regional climate properties in order to establish discriminative daily weather types on MSLP (or Z500) for the chosen local variable, precipitation for example, and domain of interest. As shown in Boé et al. (2006), it is also necessary to take into account the within-type variability of precipitation. To do this, a second step, based on a set of multivariate regression, is used to link aggregated precipitation within a set of spatial subdomains (the predictands) to the distances to the weather types (the predictors). The temperature as a predictor is used in the final step of the SDM. This last step involves the conditional resampling of the days of the training period based on a near-neighbor approach using a distance comprising the reconstructed precipitation indices described above, the temperature index and the weather type. This approach has been extensively validated initially for an hydro-meteorological study of the Seine watershed and later extended to the entire France in order to study the impact of climate change on the main French watersheds.

We first propose to slightly revise the algorithm for the present study which is going to focus on the French mountain areas. In particular, it is necessary to verify whether the derived weather types and other ingredients are appropriate for the mountain zones (choices of LSC and discriminated variables, domain spatial size, choice of the training period, separation of liquid and solid precipitation in the regression step, treatment of the diurnal cycle…). The adjusted algorithm will then be applied to the full suite of regional scenarios performed in Task 1. It will include the simulations performed by the coupled GCMs and the intermediary RCMs involved in the double nesting technique. For each simulation, a comparison of temperature, wind and precipitation projections will be made between the dynamical (simulated values, which are bias corrected by a new quantile-quantile mapping technique which accounts for different adjustments based on weather type occurrence) and statistical downscaling approaches. The main focus of that comparison will be to quantify the added value of the dynamical downscaling approach for a given resolution. In particular, changes in regional climate and weather will likely depend upon feedbacks involving orographic effects, land-water contrasts, soil-atmosphere coupling and mesoscale circulations. For instance, it has been shown that regional modeling can provide changes in hydrological processes not captured by statistical downscaling that could have considerable importance in impact assessment studies (Salathé et al. 2007). One such example is straightforward and very relevant to the current project: future warming can be intensified in regions where snow cover is lost due to the snow-albedo feedback (Hall and Qu 2007). Snow-albedo feedback follows from the decreased albedo of the underlying land surface relative to snow and the consequent increased absorption of solar radiation when snow cover is lost. This effect is likely to be most pronounced near the present-day snowline where snow-cover is the most sensitive to temperature changes. Coarse-resolution models, however, do not realistically represent this effect at regional scales since they do not resolve the slopes and elevations of the local topography. Statistical downscaling may potentially account for this effect if based on a very high spatial resolution observed dataset. However, statistical downscaling can only produce changes which are within the observed variability while regional modeling has the potential to represent amplifying feedbacks and changes exceeding the current distribution (PDF). In order to fully realize this advantage, regional models have thus to be of sufficiently fine resolution so they may properly represent the regionally important mesoscale processes and feedbacks. Another example is the role of various processes controlling evapotranspiration in shaping the summer precipitation and temperature response to anthropogenic forcing (Boé and Terray 2008). Furthermore, the sensitivity of the LSC predictors to the model resolution and the resulting impact will be investigated by comparing the statistical downscaling results of the various resolutions for the same model. In particular, it is still an open question as to the minimum horizontal resolution needed to adequately simulate the response of LSC to climate change.

Task 2 includes also a simple SDM based on quantile-quantile correction (Déqué, 2007) of high resolution RCMs with respect to SAFRAN data. Such a technique will be applied to Task 1 simulations and the results will be compared with the above described weather typing based SDM.

There are few risks in this task, since quantile-quantile, as well as weather typing techniques, have been applied to smaller sets (12 INRA stations in ANR-CLIMATOR, river Seine and Somme basins in GICC-REXHYSS).

Deliverables

D2.1: new statistical downscaling algorithm adapted to mountain areas (M12, P3)

D2.2: statistical downscaling of ALADIN runs (M18, P1)

D2.3: statistical downscaling of CMIP3 runs (M18, P3)

D2.4: development of the new quantile-quantile mapping technique, comparison dynamical-statistical downscaling and influence of horizontal resolution in LSC predictors response to climate change (M24, P3)

D2.5: statistical downscaling of LMDZ runs (M30, P1)

D2.6: statistical downscaling of MAR runs (M30, P1)

D2.7: representation of critical feedbacks in statistical and dynamical downscaling (M30, P3)

1.5.3 *Task 3: High resolution database*

This project involves five partners and aims at opening to several future research projects based on evaluation of local impacts of climate change (e.g. hydrology, agronomy, land slides, tourism, ...). It must have a wide visibility beyond the project (at least 5 years after its official end). This visibility will be first ensured by a web site of the project resuming in almost real time the advance of the different tasks. It will include reports, publications and presentations. As the project will generate a huge amount (hundreds of years) of daily data at high resolution over France (about 10000 points), a basic personal computer is not sufficient. We intend to save at daily frequency:

- mean temperature
- minimum temperature
- maximum temperature
- mean relative moisture
- mean specific moisture
- mean wind velocity
- maximum wind velocity
- rainfall
- snowfall
- long-wave downward radiation
- short-wave downward radiation
- snow amount (at different elevations)

This list is not definitive and will be agreed upon by the partners. In addition, a private part of the database will include raw model data (6-hourly, model grid) with more model variables, in order to be able to face unexpected needs. These extra data will not concern CMIP3 data which have their own server. The data on the SAFRAN grid will be homogeneous amongst the models, in the sense their climatology (mean, variance, PDF) will be identical for the reference period (1961-1990) whatever the model. This is a consequence of the statistical downscaling of Task 2.

The above daily fields offer a wide panel of applications, but their extraction may be long (data will be saved in ASCII by time series for a given grid point and parameter to facilitate local studies). In order to enable synthetic approaches, we will calculate for each calendar season and each decade a certain number of indices. Most indices will be those of the European project STARDEX (Goodess, 2003) because they have become a standard to evaluate extreme events in the modeling community. We need to add indices for snow amount and maximum wind, because STARDEX approach is based on temperature and precipitation only.

In addition to numerical data, the database will propose maps over France of the above indices for the three 30-year periods (reference, mid-century, end of century). These maps will show the uncertainty about the results, according to display methods which need to be discussed during the project.

The risk in this task is the late delivery of the server, or technical problems with this material. This will not prevent the project progress, as we can use temporarily the Météo-France computing and archiving facilities, with the restriction that they are not in public access.

Deliverables

D3.1 web site of the project (M12, P1)

D3.2 database with outputs of the project (M36, P1)

1.5.4 *Task 4: Changes in snow cover over France*

Changes in snow cover at the scale of France will be assessed using the three layer snow model of the ISBA surface scheme (Boone and Etchevers, 2001). This snow cover model is called ES (explicit snow) as it simulates a separate energy budget for the snow and the soil. It is an improvement by comparison with the snow cover model used in ALADIN, which computes only one energy budget at the surface. ISBA-ES simulates explicitly the snow water content, which has been proved to play a significant role in the melting processes during the intercomparison project SnowMIP1 (Etchevers et al., 2004). It has been compared with the detailed snow cover model CROCUS in Boone and Etchevers (2001) and is a good compromise in terms of quality and computer cost between the simple parameterization used in GCMs and detailed snow models.

ISBA-ES will be run using the meteorological data downscaled on the 8x8km grid by Tasks 1 and 2. The high number of runs will allow to address the issue of uncertainty associated to the emission scenarios and both regional and statistical downscaling. ISBA-ES will be run on all grid points over France. In mountain areas (grid points with mean elevation above 600m), ISBA-ES will be run in several instances with different surface elevations. This allows, to the first order, to take into account the fact that a 8km by 8 km box contains mountain and valley which receive the same water and energy fluxes from the atmosphere, but behave differently in terms of surface snow amount.

Snow cover characterization and evolution can hardly be addressed using a single index. Winter tourism is influenced by the amount of snow in winter (with a particular emphasis on school holidays). Estimation of water resources is more dependent on snow melt during winter (increase of winter discharge in mountain rivers) and in spring (peak snow melt discharge). It is out of the scope of this project to go into details into the impact on systems and sectors influenced by snow, but we will use the results of previous impact studies to define relevant indices. We anticipate to calculate indices relative to snow depth (maximum, averaged over a given period such as winter holidays), snow cover duration, or some more integrated indexes such as the number of days with snow depth above 30 cm, which has been used in previous Swiss studies to determine the economical viability of winter ski resorts (Elsasser, H. and Bürki, 2002). Indices related to water resources will be based on reviews of previous French studies (Etchevers et al., 2002 , Caballero et al., 2007, Boé 2007): snow water equivalent over a given region, or as a function of elevation will be studied.

The present climate (1961-1990) will be simulated and validated by using the snow cover simulated within the SAFRAN-ISBA-MODCOU suite (Habets et al., 2008) whose meteorological inputs are also provided by the SAFRAN analysis on the 8x8 km grid. This step is absolutely necessary to evaluate the quality of the downscaled snow cover with respect to the reference constituted by the ISBA-ES snow model forced by the SAFRAN analysis.

On the future periods, the defined indices will be calculated and compared with those obtained for the present climate. Spread between scenarios will be discussed in terms of uncertainties, in relation with Task 7.

In case of failure when running ISBA-ES from RCM data (very unlikely), a backup is provided by the snow amount calculated internally by the RCM surface schemes. For CMIP3 models, we do not need GCM snow data in any case: indeed, in the case of weather typing based SDM there are no risk, since SAFRAN analyses are typically defined to force ISBA model.

Deliverables

D4.1 preparing ISBA-ES to run on multi-elevation SAFRAN grid from RCM 6-hourly output (M12, P1)

D4.2 ISBA-ES simulations with CMIP3 scenarios (M 24, P1)

D4.3 ISBA-ES simulations with ALADIN scenarios (M 24, P1)

D4.4 ISBA-ES simulations with LMDZ scenarios (M 33, P1)

D4.5 ISBA-ES simulations with MAR scenarios (M 33, P1)

1.5.5 Task 5: Massif-scale changes in snow over the Alps

In this section “massif” means a subdivision of a mountain area, like “Massif des Ecrins” not like “Massif Central”. Task 5 aims at adapting the RCM scenario results to the specific mountain environment and to study the effect of climate warming on the snow pack evolution. The main three objectives are :

- to compare the RCM results 1961-1990 for the Alps with a fine scale (existing) climatology derived from ECMWF reanalyses and observations using SAFRAN,
- to derive the surface meteorological parameters at the massif scale from the results of dynamical and statistical downscaling described in Tasks 1 and 2 for the periods 2021-2050 and 2071-2100,
- to simulate a corresponding future snow pack for the French alpine massifs with the CROCUS model and to analyze the snow cover general features evolution (duration, average and maximum accumulation,…) compared to the present state. The MEPRA model will also be used in order to estimate the snow stability evolution from the CROCUS results.

Comparison of RCM results with the climatology for the Alps

The meteorological parameters and snow pack main features have been simulated by using the SAFRAN-CROCUS-MEPRA models for the Alps. SAFRAN, already mentioned in Tasks 2 and 4, is a meteorological model which allows meteorological analysis of surface parameters adapted to mountainous areas by taking into account the elevation, slope and aspect effects (Durand et al., 1993). Input data are observations (for analysis) and atmospheric model outputs. The characteristic scale used for mountainous area is the massif, which is a climatically homogeneous area of about 400 km^2. For each massif, different areas are considered with various elevation and aspect. Hence, the French part of the Alps is divided into 23 massifs. CROCUS is a detailed 1D snow model, which simulates the hourly snow pack evolution with an additional slope aspect (20° and 40°), using the meteorological surface parameters (Brun et al., 1989, 1992). It explicitly simulates the snowpack interactions with atmosphere and internal processes. MEPRA uses the CROCUS results in order to estimate the snowpack stability with a mechanical analysis (Giraud, 1993). The results of the three models (i.e. SAFRAN, CROCUS and MEPRA) have been validated for various sites and massifs, particularly for the Alps massifs (Martin et al., 1994, Durand et al., 1999). They have been run for the Alps from 1958 to 2006, providing a complete database of the alpine snow climatology (Durand et al., 2008, submitted). This database is a relevant reference to compare the results from the RCMs for the Alps. For instance, it will be particularly useful to estimate the quality of the RCM temperature and precipitation field for various massifs and elevations.

Producing the meterorological surface parameters at the massif scale for the different downscaling methods described in Tasks 1 and 2

The downscaling procedures which will be used in SCAMPEI are derived from those previously developed in the framework of the GACH2C ACI project (Malet et al., 2007) and applied on particular sites. The challenge of the present project is the spatialization of the procedures in order to calculate an accurate and spatially coherent estimation of the climate change impact over the numerous elevation and aspects of the alpine massifs. We need to downscale the numerically simulated characteristics of the reference and future climates at the grid point scale to our massif, taking into account the uncertainties. Different disaggregation methods could be used: all of them consist of computing perturbations (differences or ratios) which are combined to present climate conditions (from the above described SAFRAN climatology) at hourly timestep. The downscaling method will take into account both the main statistical features of the future climate and as far as possible the variability of extreme events.

The scenarios that will processed will be a selection of downscaled data from Task 2, including different AR4 GCMs, different high resolution RCMs and different greenhouse gas concentration assumptions.

Snowpack evolution

Using the downscaled scenarios for the Alps massifs described just above, the CROCUS-MEPRA will be run to simulate the snow pack typical of the climate conditions of the mid and end of the century. The results will be compared to present state of the snow pack and the main evolution in terms of snow depth, snow cover duration … will be analyzed. Particular features will be brought into light, as regional specificities or elevation effect. Trends on snow stability will also be considered. A particular attention will be paid to extreme meteorological events simulation by scenarios (like heavy snowfalls), which have a direct effect on critical avalanche events.

Using SAFRAN-CROCUS-MEPRA as a dynamical downscaling tool has been already carried out with coarse GCM outputs in the past. The risk of failure is therefore minimum. In such an unlikely case, Task 4 would produce snow amount data with a coarser method over the Alps.

Deliverables

D5.1 preparing CROCUS version and choice of the scenarios to be processed (M12, P1)

D5.2 CROCUS simulations with CMIP3 scenarios (M 24, P1)

D5.3 CROCUS simulations with ALADIN scenarios (M 24, P1)

D5.4 CROCUS simulations with LMDZ scenarios (M 33, P1)

D5.5 CROCUS simulations with MAR scenarios (M 33, P1)

D5.6 MEPRA analysis (M36, P1)

1.5.6 *Task 6: Impacts of future climatic change on debris flows*

Hill slope debris flows can be defined as a rapid mass movement and are common in the Alpine environment. The geometrical and sedimentological characteristics of these fast flowing mixtures of sediment and water have been observed in a wide range of mountain environments. It is well known that two conditions are needed for debris flow to be triggered: long duration or high intensity of heavy rainfalls and a large volume of debris.

As it is known that in summer hill slope debris flows are mainly triggered by intense rainy events, a change in global climate in the future could have an impact on the occurrence of this process. In addition increasing average and extreme temperatures are also expected to accelerate the retreat of glaciers and degradation of permafrost, potentially resulting in increased slope instability and related processes like debris flows.

Our approach will consist in exploiting our recently published results (Jomelli et al., 2007a, b) and will be based on following steps. In a first step we will document past and current debris flows activity. Debris flows paths will be selected in different part of the French Alps (Hautes-Alpes, Isère and Haute-Savoie regions). Those already collected in the Massif des Ecrins (Jomelli et al., 2007b) will be added to the data base. Each debris flow path will be documented regarding the geomorphic characteristics (lithology, altitude of the triggering zone, type of vegetation…). All the information will be stored in a GIS. Debris flows will be dated by combining four approaches: aerial photographs, old documents (Office National des Forêts, Restauration des Terrains en Montagne, Archives départementales) and dendrochronology especially useful to date debris flows triggered between the acquisition dates of two aerial photographs. In a second step, a stochastic model (logit, or neural network) will be used to document relationships between occurrence of debris flows and the current climate. This model will be established from the survey of debris flows triggered between 1952 and 2008, and weather parameters provided by meteorological stations. Hence, the method applied in the project will be the same as the one already applied in the Massif des Ecrins (Jomelli et al., 2007b) and will consist in:

- forcing this probability model by exchanging observed climatic parameters with those resulting from simulations provided by the regional models;
- comparing the probabilities of triggering of simulated events for the current period with those estimated for the next decades and the end of the century at both regional and local scale.

In order to estimate the impacts of future climatic change on the spatial distribution of this process, stochastic models that will be applied are spatially-distributed and embedded in GIS tools that will allow direct identification of risk areas. This step will consist in modeling the potential, direct and indirect impact of the debris flows on the alpine highway and railway networks. These linear infrastructures are particularly vulnerable to the natural hazards. They are an essential component of the economic activity of these mountainous areas and transborder exchanges, which gives a highly strategic character to them.

The analysis of vulnerability of the networks will be done on two scales:

- at the local level by the measurement of the physical damage of the network sections (1)
- at the regional level by the modeling of the dysfunction on the whole network for various scenarios of interruption (2)

The measurement of the structural vulnerability (1) will be established by means of matrices of structural damage. These matrices will give the correspondences, in term of level of damage, between the magnitude of the debris flow (volume, velocity, density) and the nature of the network. These matrices result from previous studies of Leone (1996). They could be supplemented by new bibliographical analyzes and new back analysis on damage. Each zone of potential damage will be georeferenced and described within a GIS.

The measurement of the functional vulnerability (2) will be done by means of the graph theory (MapNod software: http://mapnod.free.fr) and making of matrices of interruption (relation between structural damage / duration of interruption). In parallel, the strategic value of each network section will be measured by means of indicators integrating the traffic and accessibility. The crossing of the indices of strategic value and the probabilities of interruption will lead to a map of the risk of dysfunction for the whole network.

These experiments could be realized on various well informed geographical areas in term of debris flow hazard. The models of dysfunction of the networks will be then diversified for various scenarios of debris flow triggering.

A last stage will consist in quantifying the direct and indirect economic losses associated with each scenario of dysfunction. The direct losses will be estimated according to the foreseeable levels of damage (costs of repair or replacement). The indirect losses will be measured through the fall of economic activity induced by the problems of accessibility of the people and the goods on various portions of the territory.

This work of quantification of the direct and indirect risk related to the interruption of the networks by debris flows is innovative. It will make it possible to direct the choices of land planning and protection in the perspective of a climate warming and its effects towards the accessibility of the alpine zones.

As the methods proposed in this task are partly new, there is still a risk of failure. However a probability model has been successfully designed for Massif des Ecrins from previous ARPEGE scenarios. Failures in this task will not affect the rest of the project.

Deliverables

D6.1 Definition, calibration and application to downscaled scenarios of probability model (M33, P4)

D6.2 Risk quantification of network interruption by debris flows (M33, P4)

D6.3 Publication of the results in peer review journals (M36, P4)

1.5.7 Task 7: Evaluation of uncertainties

Climate projections for the 21st century rely upon global and regional climate models which are the only tools currently available to us for simulating the complex set of processes that determine climate at global and regional levels. It is important to remember that they represent **our current best understanding** of how the climate system works.

Many studies have recently tried to better understand and quantify the different sources of uncertainties in global climate projections for the 21st century. The problem is even more difficult if one is interested in regional and sub-regional scale projections. When analyzing fine-scale projections, the full cascade of uncertainty through the chain of external forcing, global and regional models and/or statistical techniques has to be considered. The first (not necessarily in terms of amplitude and often called the **reflexive uncertainty**) source of uncertainty is linked to the greenhouse gas emission scenario. This reflects uncertainties in the key assumptions and relationship about future population, socio-economic development and technical changes. The second source of uncertainty is linked to the greenhouse gas concentration scenarios used as external forcing of the climate models. This represents uncertainties in the understanding and representation of the processes involved in the carbon cycle and chemistry models. This aspect will not be treated within this project. The third source is the climate model uncertainty and is linked to incorrect, incomplete or missing representation of key processes within the modeled climate system (clouds, hydrological cycle, ocean heat uptake …). The second and third sources can be termed the **epistemic uncertainty**. The fourth source is linked to the natural variability of the climate system (whether it is of external – volcanic and solar forcing – or internal – feedbacks and low frequency variability within the system – nature). It is also linked to the uncertainty about the initial state of the slow component of the system, the ocean, and of the thermohaline circulation in particular. This fourth source is often called the **chaotic or stochastic uncertainty**. All of these sources of uncertainties are usually estimated with ensemble-type methods. In addition to the uncertainties described above, it is important to recognize that there are also uncertainties regarding the climate impacts themselves.

Within SCAMPEI, we have a double objective as far as the uncertainty in climate projections for the French mountain areas is concerned. We first want to quantify various (but not all) sources of uncertainty using some standard and more original approaches. One of the project focuses will be to assess how the uncertainty hierarchy evolves with time. It is likely that the sources of uncertainty for the past and the future will be different: the relative contribution of internal variability to the uncertainty in the future will likely be smaller and that of the modeling and concentration scenario uncertainties larger. Our second objective is to initiate methodological developments with the aim of reducing some sources of uncertainty and in particular, the epistemic uncertainty. Both dynamical and statistical downscaling results will be combined to provide the uncertainty assessment.

The reflexive uncertainty will be dealt with by considering a range of plausible ways in which the world might develop (also called the IPCC SRES - Special Report on Emissions Scenarios - scenarios). It will be estimated with the three ALADIN simulations. The epistemic uncertainty related to regional models will be estimated by comparing the three RCMs (ALADIN, LMDZ and MAR) for the same SRES scenario, A1B. The part linked to global models will be estimated using statistical downscaling applied to the full CMIP3 ensemble. We will use the spread between the downscaled CMIP3 ensemble simulations as a simple measure of the uncertainty (meaning here both modeling errors and internal variability). While there is no strong evidence that the model dispersion can provide an either upper or lower bound to the true uncertainty for a given region or variable, it is probably the most meaningful measure of epistemic uncertainty that is currently available (Raisanen 2007). We will further apply a recently developed method which allows generating projection-distribution functions quantitatively by resampling much smaller ensembles instead of using spaghetti diagrams (Dettinger 2007). In this first phase, all climate scenarios will be considered equally plausible and no weighting will be applied.

Our approach to reducing epistemic uncertainty is based on the concept of observable and be viewed as a process-based metrics. Here, the idea is to first identify the set of key processes in the present climate which are responsible for the projection spread of a given variable in the future climate. The second step is to compare the representation of these key processes in the present climate between the models and the observations. For instance, Boé and Terray (2008) have shown that an important fraction of the spread in projections of European summer evapotranspiration is likely to be due to the unrealistic representation of evapotranspiration control mechanisms in some models for the current climate. Using this process-based metrics to constrain regional future climate change leads (in this case, not necessarily always) to a reduction of the modeling uncertainty and to a best guess (ensemble mean) temperature regional projection of slightly larger amplitude for the European summer. Similar process-based metrics have already been proposed by other authors in various contexts (Douville et al. 2006, Hall et al. 2008). All these aspects will be further studied in the project with a particular focus on the snow-albedo and soil moisture-evapotranspiration feedbacks. Attention will be given to mean changes as well as to distribution tails. The third step consists in attributing a weighting function representing the ability of a model to simulate these key processes. This weighting function can then easily be used to condition the resampling probabilities within the estimation of the projection distribution function previously mentioned.

Deliverables

D7.1: First assessment of the various sources of uncertainties involved in climate projections (for 2021-2050 and 2071-2100) for mountain areas (M30, P3)

D7.2: Identification of key mechanisms responsible for the spread in climate variables (M30, P3)

D7.3: Second assessment of the epistemic uncertainty using process-based metrics and resampling projection-distribution technique (M36, P3)

1.6 *Expected results and potential impact*

The main expected scientific result is the added value of high resolution both numerical and statistical downscalings which will allow evaluation of the **vulnerability at very local scale**. The evaluation by original methods of uncertainty about local climate change emerging from various sources will be the second scientific outcome of the project.

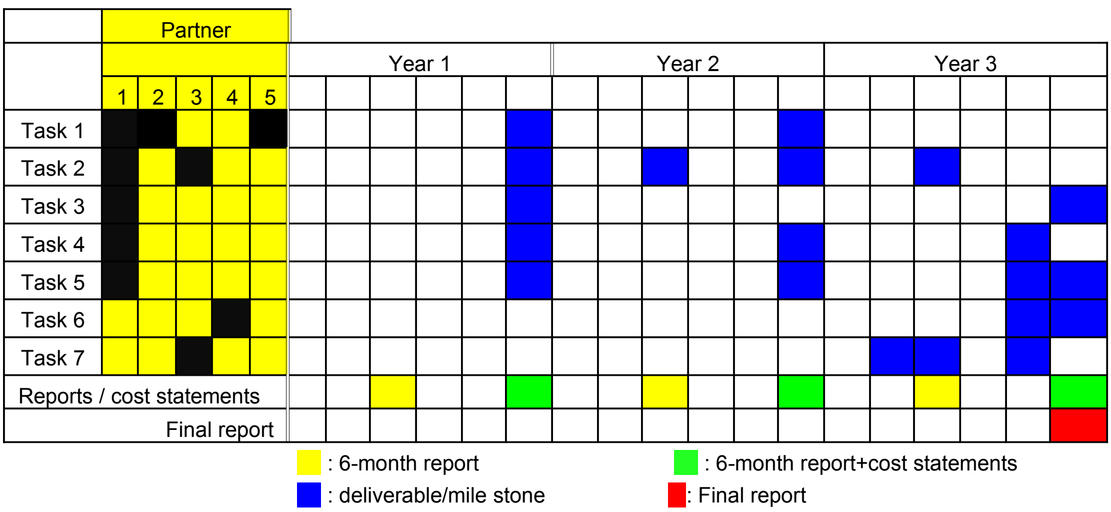
The results from this project will open the way to new projects concerning hydrology. Although it is not explicitly addressed in the SCAMPEI project, impact of climate change on hydrology is a major concern and already conducted studies (Etchevers et al., 2002 , Caballero et al., 2007) could be updated in a future project.

Preliminary results from the scenario downscaling of SCAMPEI (deliverable D2.2) will be provided at month 18 to VAMOS (VulnerAbility of MOuntain Slopes to global changes). This project is submitted to the same VMCS call and needs high resolution meteorological scenarios as an input. It addresses the vulnerability to land slides in the Alps (not to be confused with debris flows).

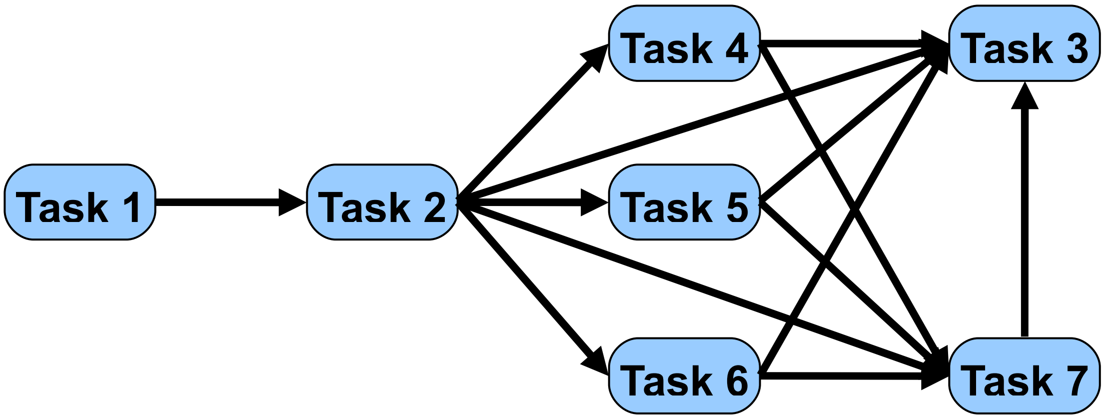
The SCAMPEI project does not involve directly socio-economical partners. But the diffusion of the comprehensive results through the project web site will enable further socio-economical studies. Météo-France is faced to a recurring demand about the future of snow in the French ski resorts with the expected climate warming (see for instance OCDE, 2007). Presently the answer is based on a combination of large-scale winter warming (typically +1°C in 50 years) and a 6.5°C/km vertical gradient to estimate the lift of the 0°-isotherm. The SCAMPEI outcome will provide a more reliable response. The database will be hosted by a dedicated server (fast PC with large disk capacity) maintained by GAME and connected to Internet (public access).

1.7 *Project flow*

The project consists of tasks which produce deliverables. The tasks and deliverables have been described in section 1.5. Here we summarize this organization. The first diagram shows the chronological organization of the tasks. The second diagram shows the logical links between the tasks. The following tables (one per task) indicate for each deliverable the time of delivery and the partner in charge of the delivery.



Chronology of the tasks



Flow dependency between the tasks

Deliverables and milestones			
Task	Title and substance of the deliverables and milestones	Delivery date, in months starting from T0	Partner in charge of the deliverable/ milestone
1			
	D1.1 ALADIN simulations	12	1
	D1.2 LMDZ simulations	24	2
	D1.3 MAR simulations	24	5
2			
	D2.1 new statistical downscaling algorithm adapted to mountain areas	12	3
	D2.2 statistical downscaling of ALADIN runs	18	1
	D2.3 statistical downscaling of CMIP3 runs	18	3
	D2.4 dynamical versus statistical techniques	24	3
	D2.5 statistical downscaling of LMDZ runs	30	1
	D2.6 statistical downscaling of MAR runs	30	1
	D2.7 representation of critical feedbacks in statistical and dynamical downscaling	30	3
3			
	D3.1 web site of the project	12	1
	D3.2 database with outputs of the project	36	1
4			
	D4.1 preparing ISBA-ES to run on multi-elevation SAFRAN grid from RCM 6-hourly output	12	1
	D4.2 ISBA-ES simulations with CMIP3 scenarios	24	1
	D4.3 ISBA-ES simulations with ALADIN scenarios	24	1
	D4.4 ISBA-ES simulations with LMDZ scenarios	33	1
	D4.5 ISBA-ES simulations with MAR scenarios	33	1
5			
	D5.1 preparing CROCUS version and choice of the scenarios	12	1
	D5.2 CROCUS simulations with CMIP3 scenarios	24	1
	D5.3 CROCUS simulations with ALADIN scenarios	24	1
	D5.4 CROCUS simulations with LMDZ scenarios	33	1
	D5.5 CROCUS simulations with MAR scenarios	33	1
	D5.6 MEPRA analysis	36	1
6			
	D6.1 flows triggering probability	33	4
	D6.2 Risks analysis	33	4
	D6.3 Publications	36	4
7			

	D7.1: Uncertainty assessment (no weighting)	27	3
	D7.2: Identification of key processes	30	3
	D7.3: Uncertainty (process metrics)	33	3

1.8 *Consortium organisation*

1.8.1 *Consortium relevance*

GAME is relevant in SCAMPEI for three reasons:

- Its 15 year experience in regional climate modeling, as well as the daily operational use of ALADIN over the same period in short-range weather prediction make it credible for the planned experiment.
- GAME has also a solid tradition (about 25 years) in meso-scale and surface modeling with internationally renown tools such as ISBA and SAFRAN.
- GAME includes an institute in Grenoble (CEN) devoted to snow research. One of its main outcome is the CROCUS model.

LMD and LGGE have both a good experience in regional climate modeling. LMD has a long tradition of cooperation with the Toulouse part of GAME, whereas LGGE has strong collaborations with the Grenoble part of GAME (CEN). GAME, LMD and LGGE represent the three French RCMs (resp. ALADIN, LMDZ and MAR) available to date.

CERFACS has also capacities in numerical climate modeling, but has in the past few years developed a knowledge in statistical downscaling based on an original approach using weather typing. It is thus a strong component of the project, as it enables to enlarge the uncertainty assessment to scenario simulations produced outside France, for instance in the IPCC-AR4 exercise.

LGP is the French reference laboratory for the physical aspects of debris flows. As the project is targeted to the mountain areas, this phenomenon is worth taking into account.

1.8.2 *Added value of the consortium*

As this project addresses the question of uncertainty, and as most of the uncertainty here comes from numerical modeling, this project needs different numerical approaches (GAME, LMD and LGGE). But uncertainty would be underestimated if we do not take into account the international context of IPCC. Thanks to an original approach of CERFACS, we can evaluate the spread of the various scenarios at the same resolution as the high resolution RCMs of the project. The comparison between high and low resolution inputs to the statistical downscaling will validate or invalidate such an approach.

As this project addresses the question of vulnerability, we must tackle with phenomena for which the society is vulnerable. One is the winter snow amount; it will be studied by the CEN part of GAME. Another one is debris flows, which needs the inclusion of the LGP partner.

For the reasons of size and feasibility, the project does not address the important question of water resources and hydrology, which would constitute a project *per se*. But SCAMPEI allows such a project to emerge later on, thanks to the high resolution (in time and space) database which will be created.

Four out of the five partners, namely GAME CERFACS LMD and LGP, have already worked together in 2002-2004 in the GICC-IMFREX project on the impacts over France of the change in the frequency of extreme climatic events in the expected climate change. Some of the techniques proposed in SCAMPEI have been used in an earlier form in this project. We expect the partner cooperation in SCAMPEI will be as successful as it was in IMFREX.

To facilitate exchange between Toulouse, Paris and Grenoble which are the three poles of the project, two meetings per year will be organized.

1.8.3 *Principal investigator and partners : résumé and CV*

See annexes for partner description and involvement in other projects. Sections 1.2, 1.3 and 1.4 have explained the originality of the project with respect to the recent or current European projects. Since the planned climate simulations will be new, there is no overlap with current ANR projects, which are based on already existing coarser resolution regional climate simulations.

1.8.4 *Partners qualification*

Partner 1: GAME	Name	First name	Status	Domain	men-months	role in the project
Principal Investigator	Déqué	Michel	IPC	Numerical modeling	12	project coordination, analyses
	Somot	Samuel	IPC	Numerical modeling	5	ALADIN simulations
	Braun	Alain	ITM	computing	8	project database and web page
	Ribes	Aurélien	IPC	Statistics	3	downscaling of RCM simulations
	Martin	Eric	IPC	Surface processes	5	ISBA-ES modeling
	Durand	Yves	IPC	Meteorology	3	SAFRAN downscaling
	Etchevers	Ingrid	ITM	Meteorology	6	SAFRAN downscaling
	Etchevers	Pierre	IPC	Snow modeling	3	CROCUS modeling
	Giraud	Gérald	ITM	Snow modeling	6	CROCUS modeling, MEPRA downscaling
	Mérindol	Laurent	TSM	Meteorology	6	SAFRAN downscaling
	Navarre	Jean-Pierre	IPC	Snow modeling	3	MEPRA downscaling

Partner 2: LMD	Name	First name	Status	Domain	men-months	role in the project
Principal Investigator	Li	Laurent	DR2	Climate modeling	7.2	Simulation and analysis
	Musat	Ionela	IE	Climate modeling	7.2	Simulation and analysis
	Casado	Alberto	Ph.D student	Climate modeling	7.2	Simulation and analysis

Partner 3:CERFACS	Name	First name	Status	Domain	men-months	role in the project
Principal Investigator	Terray	Laurent	DR	Climatology	15	analyses, uncertainties and process based metrics
	Pagé	Christian	IR	Downscaling	9	Statistical downscaling
	Maisonnave	Eric	IR	Computing optimization	3	Numerical algorithms optimization and porting

Partner4: LGP	Name	First name	Status	Domain	men-months	role in the project
Principal Investigator	Jomelli	Vincent	CR1	Geomorphology	7.2	Impacts on magnitude-frequency, Hazard analysis
	Grancher	Delphine	IE	Statistics	7.2	Stochastic models (neural network, logit), relationships between debris flows and climate
	Brunstein	Daniel	IR	SIG	3.6	SIG conception
	Leone	Frédéric	MCF	Risk analysis	7.2	Economic and functional vulnerability of highway and railway networks

Partner 5: LGGE	Name	First name	Status	Domain	men-months	role in the project
Principal Investigator	Gallée	Hubert	DR	Regional Climate Modeling	15	MAR modeling, analysis of results
	XX	XX	PhD student	alpine climate modeling	24	Physical disagregation of precipitation and surface energy balance at the kilometric scale

IPC=Ingénieur des Ponts et Chaussées, ITM=Ingénieur des Travaux de la Météorologie, TSM=Technicien de la Météorologie, DR=Directeur de Recherches, CR=Chargé de Recherches, IR=Ingénieur de Recherches, IE=Ingénieur d'Etudes, MCF=Maître de Conférences

1.9 *Data management, data sharing, intellectual property strategy, and exploitation of project results*

The models and raw data used in the project belong to the partners who bring them (e.g. ALADIN model or SAFRAN reanalysis). They will be exchanged between the partners during the project in each case it is necessary to produce a deliverable. They can be provided outside the project for research purposes, after signature of a convention between the two institutes involved.

The data produced by the project: presentations, reports, publications, database (Task 3) are public.

1.10 *References*

Beniston, M., 2003: Climatic change in mountain regions: A review of possible impacts. Climatic Change 59, 5-31.

Beniston, M., 2006: Mountain Weather and Climate: A General Overview and a Focus on Climatic Change in the Alps. Hydrobiologia 562, 3-16.

Boé J., L. Terray, F. Habets and E. Martin, 2006: A simple statistical-dynamical downscaling scheme based on weather types and conditional resampling J. Geophys. Res., 111, D23106.

Boé J., L. Terray, F. Habets and E. Martin, 2007: Statistical and dynamical downscaling of the Seine basin climate for hydro-meteorological studies. Int. J. Clim., 27(12), 643-1655, doi:10.1002/joc.1602.

Boé, J. 2007: Changement global et cycle hydrologique : Une étude de régionalisation sur la France. Université de Toulouse (Toulouse III - Paul Sabatier), Novembre 2007.

Boé, J. and L. Terray, 2008: Uncertainties in summer evapotranspiration changes over Europe and implications for regional climate change. Geophys.Res.Lett., 35, L05702, doi:10.1029/2007GL032417.

Boone, A. and P. Etchevers, 2001: An inter-comparison of three snow schemes of varying complexity coupled to the same land-surface model: Local scale evaluation at an Alpine site, J.Hydrometeorol., 2, 374-394.

Brasseur O., H. Gallée, J.D. Creutin, T. Lebel and P. Marbaix, 2001: High resolution simulation of precipitation over the Alps with the perspective of coupling to hydrological models. Advance in Global Change Research, 10 (M.Beniston, Ed.),75-100.

Brasseur O., H. Gallée, H. Boyen and C. Tricot, 2002: Reply to comments on : Development and application of a physical approach to estimate wind gusts. Monthly Weather Review, 130, 1936-1942.

Brun, E, E. Martin, V. Simon, C. Gendre and C. Coléou, 1989: An energy and mass model of snow cover suitable for operational avalanche forecasting. Journal of Glaciology 35(121): 333-342.

Brun, E, P. David, M. Sudul and G. Brugnot, 1992: A numerical model to simulate snow cover stratigraphy for operational avalanche forecasting. Journal of Glaciology 38(128): 13-22.

Bubnová R., G. Hello, P. Bénard and J.F. Geleyn, 1995: Integration of the fully elastic equations cast in the hydrostatic pressure terrain-following coordinate in the framework of ARPEGE/Aladin NWP system. Monthly Weather Review, 123, 515-535.

Caballero, Y., S. Voirin-Morel, F. Habets, J. Noilhan, P. LeMoigne, A. Lehenaff and A. Boone, 2007: Hydrological sensitivity of the Adour-Garonne river basin to climate change, Water Resour. Res., 43, W07448, doi:10.1029/2005WR004192.

Christensen, J.H. and O.B. Christensen, 2007: A summary of the PRUDENCE model projections of changes in European climate by the end of this century, Climatic Change, 81, 7-30.

Dettinger, M.D., 2006: A Component-Resampling Approach for Estimating Probability Distributions from Small Forecast Ensembles. Climatic change, 76, 149-168.

Déqué, M., 2007: Frequency of precipitation and temperature extremes over France in an anthropogenic scenario: model results and statistical correction according to observed values. Global and Planetary Change, 57, 16-26.

Déqué, M. and S. Somot, 2008: Added value of high resolution for ALADIN Regional Climate Model. Submitted to Research Activities in Atmospheric and Oceanic Modeling.

Douville H., D. SalasMélia and S. Tyteca, 2006 : On the tropical origin of uncertainties in the global land precipitation response to global warming. Clim. Dyn., 26, 367-385.

Durand, Y., E. Brun, L. Mérindol, G. Guyomarc'h, B. Lesaffre and E. Martin, 1993: A meteorogical estimation of relevant parameters for snow models. Annals of Glaciology, 18, 65-71.

Durand, Y., G. Giraud, E. Brun, L. Mérindol and E. Martin, 1999: A computer based system simulating snowpack structures as a tool for regional avalanche forecast. Journal of Glaciology, 45(151), 469-485.

Durand, Y., M. Laternser, G. Giraud G., P. Etchevers, B. Lesaffre and L. Mérindol, 2008: Reanalysis of 44 years of climate in the French Alps (1958 – 2002). Part I: Methodology, model validation and Temperature, precipitation AND snowfall trends. Submitted to International Journal of Applied meteorology and climatology.

EEA 2004. Impacts of Europe's changing climate – an indicator-based assessment. Report no2, European Environment Agency, Copenhagen, 107 pp.

Elsasser, H. and R. Bürki, 2002: Climate Change as a threat to tourism in the Alps. Climate Research, 20, 253-257.

Etchevers P., E. Martin, R. Brown, C. Fierz, Y. Lejeune, E. Bazile, A. Boone, Y.-J. Dai, R. Essery, A. Fernandez, Y. Gusev, R. Jordan, V. Koren, E. Kowalczyk, N. O. Nasonova, R. D. Pyles, A. Schlosser, A. B. Shmakin, T. G. Smirnova, U. Strasser, D. Verseghy, T. Yamazaki and Z.-L. Yang, 2003: Intercomparison of the surface energy budget simulated by several snow models (SNOWMIP project), A. of Glaciology, 38, 150-158.

Etchevers, P., C. Golaz, F. Habets and J. Noilhan 2002: Impact of a climate change on the Rhone river catchment hydrology. Journal of Geophysical Research 107 (10.1029/2001JD000490). 2, 374-394.

Fettweis, X., J.-P. Van Ypersele, H. Gallée, F. Lefebre and W. Lefebvre, 2007: The 1979–2005 Greenland ice sheet melt extent from passive microwave data using an improved version of the melt retrieval XPGR algorithm, Geophys. Res. Lett., 34, L05502, doi:10.1029/2006GL028787.

Gallée H., G. Gyomarc'h and E. Brun, 2001: Impact of the snow drift on the antarctic ice sheet surface mass balance: a sensitivity study to snow surface properties. Boundary Layer Meteorology 99, 1-19.

Gallée, H., V. Peyaud and I. Goodwin, 2005: Temporal and spatial variability of the Antarctic Ice Sheet Surface Mass Balance assessed from a comparison between snow stakes measurements and regional climate modeling. Annals of Glaciology, 41, 17-22.

Giorgi, F., 1990: Simulation of regional climate using a limited area model nested in a general circulation model. J. Climate, 3, 941-943.

Giorgi, F. and L.O. Mearns, 1999: Introduction to special section: Regional climate modeling revisited. Journal of Geophysical Research-Atmospheres, 104, 6335-6352.

Giorgi, F., X. Bi and J. Pal, 2004: Mean, interannual variability and trends in a regional climate change experiment over Europe. II: climate change scenarios (2071-2100). Climate Dynamics 23, 839-858.

Giorgi, F. and X. Bi, 2005: Updated regional precipitation and temperature changes for the 21st century from ensembles of recent AOGCM simulations Geophys. Res. Lett., 32, L21715 doi:10.1029/2005GL0242880.

Giorgi, F., 2005: Climate Change Prediction. Climatic Change, 73: 239-265.

Goodess, C, 2003: STAtistical and Regional dynamical Downscaling of EXtremes for European regions: STARDEX. European Geophysical Union Information Newsletter 6, available on line at http://www.the-eggs.org/articles.php?id=37 .

Giraud, G., 1993: MEPRA: an expert system for avalanche risk forecasting. In Proceedings ISSW '92, A merging of theory and practice, International Snow Science Workshop, 4-8 October 1992, Breckenridge; 97-104.

Habets, F., A. Boone, J.L. Champeaux, P. Etchevers, L. Franchistéguy, E.Leblois, E. Ledoux, P. Le Moigne, E. Martin, S. Morel, J. Noilhan, P. Quintana Segui, F. Rousset-Regimbeau and Viennot, 2007: The SAFRAN-ISBA-MODCOU hydrometeorol-ogical model applied over France, Journal of Geophysical Research, In press.

Hall, A. and X. Qu, 2006: Using the current seasonal cycle to constrain snow albedo feedback in future climate change, Geophys. Res. Lett., 33, L03502, doi:10.1029/2005GL025127.

Hall, A., X. Qu and J. D. Neelin, 2008: Improving predictions of summer climate change in the United States, Geophys. Res. Lett., 35, L01702, doi:10.1029/2007GL032012.

IPCC, 2007: Climate change 2007. The physical science basis. Cambridge University Press, 996 pp.

Jacobeit J, H. Wanner, J. Luterbacher, C. Beck, A. Philipp and K. Sturm, 2003: Atmospheric circulation variability in the North-Atlantic-European area since the mid-seventeenth century. Climate Dynamics, 20: 341–352.

Jomelli, V., M. Déqué, D. Brunstein et D. Grancher, 2007a: Probabilités d'occurrence des coulées de débris de versant dans les Alpes françaises au 21eme siècle estimées à partir des sorties du modèle ARPEGE. Géomorphologie, 4, 283-292.

Jomelli, V., D. Brunstein, D. Grancher and P. Pech, 2007b:Is the response of hill slope debris flows to recent climate change univocal ? A case study in the Massif des Ecrins (French Alps), Climatic Change, 85, 119-137.

Lehner, B., P. Döll, J. Alcamo, T. Henrichs and F. Kaspar, 2006: Estimating the Impact of Global Change on Flood and Drought Risks in Europe: A Continental, Integrated Analysis. Climatic Change, 75, 273-299.

Malet, J.P., A. Remaître, O. Maquaire, Y. Durand, P. Etchevers, G. Guyomarch, M. Déqué and LPH. van Beek, 2007 : Assessing the influence of climate change on the activity of landslides in the Ubaye Valley. Proceeding of the Conference 'Landslides and Climate Change' Wight Island, 21-24 may 2007.

Martin, E., E. Brun and Y. Durand, 1994: Sensitivity of the French Alps snow cover to the variation of climatic variables. Annales Geophysicae, 12, 469-477.

Martin E., B. Timbal and E. Brun, 1997: Downscaling of general circulation models outputs : simulation of the snow climatology of the French Alps. Sensitivity to climate changes, Climate Dynamics, 13, 45-56.

Martin, E. and P. Etchevers, 2005: Impact of climatic change on snow cover and snow hydrology in the French Alps. In: Global Change and Mountain Regions (A State of Knowledge Overview) [Huber U. M., H. K. M. Bugmann and M. A. Reasoner (eds.)], Springer, Dordrecht, pp.235-242.

OCDE, 2007. Climate Change in the European Alps. Adapting Winter Tourism and Natural Hazards Management.

Quintana-Seguí, P., P. Le Moigne, Y. Durand, E. Martin, F. Habets, M. Baillon, C. Canellas, L. Franchisteguy and S. Morel, 2008: Analysis of Near-Surface Atmospheric Variables: Validation of the SAFRAN Analysis over France. J. Appl. Meteor. Climatol., 47, 92–107.

Radu, R., M. Déqué and S. Somot, 2008: Spectral nudging in a spectral regional climate model. Submitted to Tellus.

Räisänen, J., 2007: How reliable are climate models? Tellus A, 59, 2-29.

Rowell, D.P. and R.G. Jones, 2006: Causes and uncertainty of future summer drying over Europe, Clim. Dyn., 27, 281 – 299, doi:10.1007/s00382-006-0125-9.

Rowell, D.P., 2006: A Demonstration of the Uncertainty in Projections of UK Climate Change Resulting from Regional Model Formulation. Climatic Change 79(3-4): 243.

Salathé, E.P., P.W. Mote and M.W. Wiley, 2007: Considerations for selecting downscaling, methods for integrated assessments of climate change impacts. International Journal of Climatology, in press.

Schär, C., P.L. Vidale, D. Lüthi, C. Frei, C. Häberli, M.A. Liniger and C. Appenzeller, 2004: The role of increasing temperature variability in European summer heatwaves. Nature 427, 332-336.

Tebaldi, C., R.L. Smith, D. Nychka and L.O. Mearns, 2005: Quantifying uncertainty in Projections of Regional Climate Change: a Bayesian Approach to the Analysis of Multimodel Ensembles. J. Climate, vol. 18, no. 10, 1524-1540.

von Storch, H., 1995: Inconsistencies at the interface of climate impact studies and global climate research. Meteorologische Zeitschrift 4:72–80.

von Storch, H., 1999: On the use of “inflation” in statistical downscaling. Journal of Climate 12: 3505–3506.

2 *Requested budget: detailed financial plan*

2.1 *Partner 1*

2.1.1 *Large equipment*

The project needs a data server to deliver public results at the end of the project. The public database will contain daily data on about 10000 grid points over France (8 km resolution) for two 30-year periods (2021-2050 and 2071-2100) and for at least 12 different scenarios (6 from RCMs, 6 from IPCC), plus 3 reference simulations. This corresponds to about 50 Gigabytes per variable. From our experience of users' request, ASCII format is best suited for delivery. However, to enable fast calculation of STARDEX indices, numerical and statistical downscaling, a binary form of the data is also necessary. The server will also contain raw data from the simulations (private part), so that we need 4 Terabytes of disk space. The cost of this server is 4000€ plus 7000€ for fast disks. The heavy numerical simulations of Task 1 (about 200 years with ALADIN) will be done on Météo-France NEC mainframe computer.

2.1.2 *Manpower*

CDD1: post-doctoral position in Toulouse 24 months

The post-doctoral researcher will participate in Task 4 activities:

- he will prepare the data from different RCM and GCM on the SAFRAN grid
- he will check that the postprocessed data have no bias in the present climate
- he will prepare and run the ISBA-ES simulations on SAFRAN grid with several elevations
- he will analyze the snow cover results in the reference and scenario data

The researcher will have knowledge in climate modeling, with particular emphasis on surface/atmophere exchanges. The researcher will have a good practice in Fortran and Unix. Some statistical knowledge in data analysis is also necessary.

CDD2: post-doctoral position in GAME/CEN (Grenoble) 24 months

The post-doctoral researcher will participate in Task 5 activities:

- he will participate in the comparison of the RCM results for the Alps with the fine-scale ECMWF reanalyses
- he will downscale the RCM results for the scenarios and prepare meteorological fields at the massif scale
- he will run the SAFRAN-CROCUS-MEPRA suite and participate in the results analysis

The researcher will have knowledge in atmosphere and/or climate modeling and surface/atmophere exchanges. Knowledge in snow modeling is also welcome, but not mandatory. The researcher will have a good practice in computer science (Fortran programming) and in statistical and data analysis.

Cost of each CDD: 92760 €

2.1.3 *Services, outward facilities*

2.1.4 *Travels*

6 travels Grenoble (CEN)-Toulouse (internal project meetings) 3000€

9 travels (3 scientists each year) in international workshops (result communications) 18000€

2.1.5 *Expenses for inward billing*

2.1.6 *Other expenses*

Three additional PCs are necessary to carry out the analyses and manage the data. Two of them will be used by the two post-docs, and an additional one is necessary in Grenoble for permanent staff.

Cost: 4500€

2.2 *Partner 2*

2.2.1 *Large equipment*

Numerical simulations will be performed on the platforms of the IDRIS, the computer centre of the CNRS. No other specific equipments are necessary for the realization of the project.

2.2.2 *Manpower*

Post-doctoral position in LMD for 12 months.

The main involvement will be in the Task 1, considered as the provider of climate change information through dynamical downscaling. Specific emphasis will be given on data analysis in order to better understand the scale interaction from global models to regional models.

The cost of this post-doctoral position will be 36000€.

2.2.3 *Services, outward facilities*

2.2.4 *Travels*

6 domestic travels in France for project meetings: 3000€

3 international travels (workshop and colloquium):6000€

2.2.5 *Expenses for inward billing*

2.2.6 *Other expenses*

The purchase of two PCs is planned: 3000€

2.3 *Partner 3*

2.3.1 *Large equipment*

2.3.2 *Manpower*

CDD1: post-doctoral position in CERFACS, Toulouse 12 months

The post-doctoral researcher will participate in Task 2 and 7 activities:

- he will participate to the adaptation of the statistical downscaling to the mountaineering areas
- he will perform an extensive validation for the present climate.
- he will perform and analyze the statistical downscaling of the CMIP3 and ENSEMBLE simulations.
- he will participate to the uncertainty analysis

The researcher will have knowledge in atmosphere and/or climate modeling. The researcher will have a good practice in computer science (Fortran programming, analysis and graphic tools such as NCL) and in statistical and data analysis.

The cost is 48600€

2.3.3 *Services, outward facilities*

2.3.4 *Travels*

6 travels (Toulouse-Grenoble or Paris) for internal project meetings 3000€

3 travels in international workshops (project results communications) 6000€

2.3.5 *Expenses for inward billing*

2.3.6 *Other expenses*

One PC for the post-doc is necessary to carry out the analyses. 1500€

Publication charges 1500€

2.4 *Partner 4*

2.4.1 *Large equipment*

2.4.2 *Manpower*

PhD position: LGP (18 months).

Title: Debris flows activity hazard and risk estimation in the French Alps in future climatic change.

The 18 months Ph D position will complement a 18 month position granted within the Ministère des Affaires Etrangères and Lavoisier fundings. The doctoral research fellow will be involved in most of the activities of Task 4. The work program will consist in analyzing debris flows response to future climatic change in the French Alps, including hazard and risk estimation. The work program is based on the use of several techniques (dendrogeomorphology, statistical modeling, process-based modeling, risk analysis).

It includes the following tasks:

- Document and assess debris flows activity for the current period in Vanoise Massif through different techniques; (dendrogeomorphology, old document analysis, GIS, statistical modeling),
- Assess the return period and recurrence time for the period 1970-2010 at local scale for different debris flows paths and develop
- Develop a probability model of occurrence with geomorphic and climatic parameters for the current and future period,
- Assess debris flows susceptibility, hazard, vulnerability (potential consequences) and risks for the study areas, for both the current and the future period.

Supervision: V. Jomelli (LGP)

Involment in the project: 100% (18 months)

Cost: 49716€

CDD positions

2 CDD positions are needed for data analysis. The first one (AI level) would be devoted during 10 months to tree ring samples analysis (6 months Y1 and 4 months Y2). The second one (AI level) would be devoted to collect economic data in order to estimate debris flows impacts (3 months Y1).

Cost: 29771€

2.4.3 *Services, outward facilities*

2.4.4 *Travels*

Field trip analysis (15 days, 4 people Y1 and Y2) = 3800€ for each year (Car rental, and travel)

6 travels to project meetings (500€ each) = 3000€

2 oral presentations Y2 and Y3 at EGU (2000€ each for registration, travel and per diem). Total = 8000€

2.4.5 *Expenses for inward billing*

2.4.6 *Other expenses*

2 personal computers (1500€ each) and publication costs (2400€)= 5400€

2.5 *Partner 5*

2.5.1 *Large equipment*

2.5.2 *Manpower*

Personnel: post-doctoral position 12 months

The post-doctoral researcher will participe in Task 1 activities

- he will prepare MAR code for the simulations
- he will prepare for MAR the data generated by the LMDZ GCM
- he will manage the 3 MAR simulations

Cost: 46267€

2.5.3 *Services, outward facilities*

2.5.4 *Travels*

2 travels at international workshops: 4000€

4 travels to internal project meetings: 2000€

2.5.5 *Expenses for inward billing*

2.5.6 *Other expenses*

Two additional PCs are necessary to carry out the analyses and manage the data, one for the post-doc and one for a thesis work: 3000€

Other computing expenses (external disks for data storage): 3000€

Publication costs: 2000€

Annexes

Partners informations (cf. § 1.8.1)

Partner 1: GAME

GAME is an associate CNRS laboratory corresponding to the main part of the research institute of the French weather service Météo-France (CNRM). GAME has a long experience in developing atmospheric and surface models both for research and operational applications. Most of the research groups are in Toulouse, but the Centre d'Etude de la Neige (CEN, Center for Snow Studies) is located in Grenoble. GAME is in charge of the development of the following numerical modeling systems which will be used in the framework of SCAMPEI:

- The global climate model ARPEGE, which can be used with enhanced resolution over Europe, or which can be coupled to the global ocean model OPA
- The mesoscale climate model ALADIN. Both ARPEGE and ALADIN belong to the same numerical suite of models as ECMWF IFS forecast model.
- The ISBA soil/vegetation/snow scheme
- The CROCUS snow scheme (at CEN)
- The regional limited-area climate model ALADIN-climat

GAME has also developed a high resolution real time assimilation scheme SAFRAN in the late 1980s. A reanalysis from 1958 through 2001 is being performed (achievement summer 2008) which allows a high temporal and spatial density database of good quality over France.

GAME has been actively participating in the major European projects on regional climate change modeling since the early 1990s. GAME has also participated in the AR4 IPCC exercise with ARPEGE/OPA, and this GAME simulation will be the first step of the double nesting approach for numerical downscaling. In the CECILIA European project, GAME has produced the second step of the double nesting with a 150-year (1951-2100) simulation of the global version of ARPEGE with 50 km resolution over Europe.

In the proposal, GAME is in charge of the numerical downscaling with one of the models (ALADIN), the statistical downscaling with the model-to-reanalysis calibration method (so called quantile-quantile adjustment), the surface modeling with ISBA-ES, and the snow modeling with CROCUS and MEPRA

Partner 2: LMD

LMD is a joint research laboratory of the CNRS, Ecole Polytechnique, Ecole Normale Supérieure and the University of Paris VI. Its research program consists of studying the mechanism, the evolution and the prediction of meteorological and climatic phenomena. LMD brings its contribution to the project mainly by its modeling group. Since long time, the LMD has been involved in studies on climate change prediction and has accumulated a important expertise on climate change impacts. The global version of the LMDZ atmospheric GCM was the atmospheric component of the IPSL coupled climate model which has participated in the IPCC-AR4. The regional version of the LMDZ model is also widely used, in particular, in on-going EU-funded projects CIRCE, CLAVIER, and CLARIS.

In the proposal, LMD will provide climate change scenarios through dynamical downscaling with LMDZ, together with the expertise to understand the physical mechanisms of scale interaction.

Partner 3: CERFACS

CERFACS, established in 1987 in Toulouse, is a leading research institute working on efficient algorithms for solving large scale scientific problems. The CERFACS Climate Modeling and Global Change team conducts basic scientific research and high-level technical developments in the field of climate studies. In particular, the team develops the OASIS coupler software, currently used by more than 25 climate modeling groups around the world, and that naturally emerged as an essential element of the PRISM project. Assembling coupled GCMs using state-of-art component models, porting and optimizing them on a variety of platforms such as vector or scalar machines complement CERFACS mission in performing high resolution climate simulations. On a more scientific side, the Climate Modeling team has been involved in many studies of climate variability of internal and external origin. Recent scientific projects focus on the impacts due to anthropogenic climate change at regional scale with specific interest in the changes of extreme events distribution and hydrological cycle properties. New developments on original downscaling techniques were recently realized bridging the gap between climate model data and data needed by impact models. The team has recently produced a set of climate scenarios for France at very high spatial resolution (8 km). These scenarios are currently used within many national projects (CLIMATOR-ANR, VALIDATE-ANR, REXHYSS-GICC, QDIV-ANR) on climate impacts. Modeling the uncertainty propagation from the climate scenarios to the impact models is another transverse theme of interest.

In the proposal, CERFACS is responsible for the adaptation of the weather type-based statistical downscaling method to the French mountain areas as well as its application to several climate simulation datasets in addition to those realized within the project. CERFACS will also propose innovative strategies to cope with the various sources of uncertainty.

Partner 4: LGP

The Laboratory of Physical Geography is a Mixed Research Unit (UMR 8591) linked to both the National Centre for Scientific Research (CNRS) and the University Paris I Panthéon-Sorbonne. The laboratory encompasses more than 50 researchers and technical staff.

Headed by Prof. Charles Le Coeur, the laboratory is organized on four working groups:

The first WG is specialized in Quaternary palaeoenvironments. It is divided into three tasks which focus on long Pleistocene stratigraphic sequences, Pleistocene and Holocene fluvial systems in France and West Europe, and Late glacial and Holocene Mediterranean environments. Laboratory techniques include palynology, sedimentaolgy, geochemistry, and microbiology.

The second WG, called DYVERLI, study on the actual evolution mountain slopes (Alps, Andes, Indonesian volcanoes) and on river channel changes. The research programmes encompass studies on sediment transfer, responses to climatic and environmental change, and natural hazards and risks (debris flows, floods, landslides, lahars, etc.). Field works are mainly carried out in France, Indonesia, Latin America and Siberia.

The third WG is specialized on coastal dynamics, and focus on four main tasks: long-term sea level changes in the Past (Mediterranean Sea), recent climatic change and sea level rise (Europe), coastal dynamics and anthropic systems (West Africa, Colombia), tsunamis dynamics and impacts (Indonesia).

The fourth group studies the long term geomorphological evolution of mountain chains and sedimentary basin, using a set of dating methods like cosmonucleids (^{10}Be) or thermochronology (Fission tracks), in France (Pyrenees), Asia (India) and South America (Brazil, Perou).

In the proposal, LGP is in charge of the statistical downscaling and evaluation of debris flows over the Alps in the scenarios.

Partner 5: LGGE

LGGE (Laboratory of Glaciology and Environmental Geophysics) is a mixed research unit managed by both the CNRS (French National Centre for Scientific Research) and the Université Joseph-Fourier (UJF, Grenoble I). Within the CNRS, LGGE is primarily a part of the Sciences of the Universe department (INSU/SDU), but also the Engineering Sciences department (SPI) for its work on ice. Within the university, LGGE is a part of the Observatory for Sciences of the Universe in Grenoble (OSUG). It makes extensive use of the technical support provided by Institut Polaire Français Paul-Emile Victor (IPEV) for operations in polar regions. LGGE has built its scientific reputation on its research dealing with the climate and the composition of the atmosphere. These studies deal with the present and the past based on the natural archives of ice and snow accumulated over the ages. However, LGGE has generated other very competitive fields of competence based on ice and snow, for instance the physical and mechanical study of ice, chemical exchanges between air and snow, as well as data acquisition in the field and via satellite. The research carried out combines technological and analytical developments with a digital modeling approach covering various fields from the atmosphere to the flow of massive quantities of ice. The Arctic and Antarctic polar regions are the primary sites studied, but LGGE has considerable experience in mountain zones as well, including research on glaciers in the Alps and the Andes, and pollution in the valleys of the Alps.

In the proposal, LGGE is in charge of producing scenarios through numerical downscaling with the MAR RCM.

Résumés and CV (cf. § 1.8.3)

Michel DEQUE

Déqué, Michel, 51 years old, Ingénieur en chef des Ponts et Chaussées, HDR of Institut National Polytechnique de Toulouse (2006), head of ARPEGE-Climat (EAC) research team at Groupe de Météorologie à Grande Echelle et Climat (GMGEC) of GAME since 1991. Researcher in climate numerical modeling at Météo-France since 1980.

Michel Déqué will coordinate the SCAMPEI project. He has a long expertise (more than 25 years) in climate numerical modeling. His research group is in charge of developing a climate version of the ARPEGE/IFS forecast system used operationally by Météo-France and ECMWF. Since the early 1990s, he has been involved in most European projects dedicated to regional climate modeling over Europe. He has coordinated the European HIRETYCS project which addressed high resolution climate modeling. He has been involved, as a partner or as a data provider, in many national projects dedicated to impacts of climate change over France. He has coordinated the GICC-IMFREX project which addressed the change in frequency of extreme climatic events over France. He is member of WRCP working group on seasonal to interannual prediction and of scientific committee of INSU "les enveloppes fluides pour l'environnement" (LEFE) program. He is involved in the SGMIP (stretched grid model intercomparison project) international project endorsed by WGNE (working group of numerical experimentation of WCRP) to explore this technique in regional climate modeling.

Déqué M., Jones, R.G., Wild, M., Giorgi, F., Christensen, J.H., Hassell, D.C., Vidale, P.L., Rockel, B., Jacob, D., Kjellström, E., de Castro, M., Kucharski, F., van den Hurk, B., 2005: Global high resolution versus Limited Area Model climate change projections over Europe: quantifying confidence level from PRUDENCE results. Climate Dynamics, 25, 653-670

Fox-Rabinovitz M., J. Côté, B. Dugas, M. Déqué and J.L. McGregor, 2006: Variable resolution general circulation models: Stretched-grid model intercomparison project (SGMIP), J. Geophys. Res., 111, D16104, doi:10.1029/2005JD006520

Déqué, M., 2007: Frequency of precipitation and temperature extremes over France in an anthropogenic scenario: model results and statistical correction according to observed values. Global and Planetary Change, 57, 16-26

Déqué, M., Rowell, D.P., Lüthi, D., Giorgi, F., Christensen, J.H., Rockel, B., Jacob, D., Kjellström, E., Castro, M. ,van den Hurk, B., 2007: An intercomparison of regional climate simulations for Europe: assessing uncertainties in model projections. Climatic Change, 81, 53-70

Déqué, M. et Li, L., 2007: La prévision climatique: régionalisation et extrêmes. La Météorologie, 57, 28-30

Samuel SOMOT

Somot, Samuel, 31 years old, Ingénieur des Ponts et Chaussées. Docteur of Université Paul Sabatier (2006). Researcher in Equipe ARPEGE-Climat (EAC) at Groupe de Météorologie à Grande Echelle et Climat (GMGEC) of GAME since 2003. Responsible for climate regionalization at EAC and expert in mediterranean climate and mediterranean sea modeling at GAME.

Somot S., Sevault F., Déqué M., Crépon M. (2008) 21st century climate change scenario for the Mediterranean using a coupled Atmosphere-Ocean Regional Climate Model. Global and Planetary Change (in press, available on-line)

Somot S., Sevault F., Déqué M. (2006) Transient climate change scenario simulation of the Mediterranean Sea for the 21st century using a high-resolution ocean circulation model. Climate Dynamics, Volume 27, Numbers 7-8, December, 2006, pp. 851-879, DOI :10.1007/s00382-006-0167-z

Herrmann, M. J., and S. Somot (2008) Relevance of ERA40 dynamical downscaling for modeling deep convection in the Mediterranean Sea, Geophys. Res. Lett., 35, L04607, doi:10.1029/2007GL032442

Tsimplis M., Marcos M., Somot S. (2008) 21st century Mediterranean sea level rise: steric and atmospheric pressure contributions from a regional model. Global and Planetary Change (in press)

Somot S. (2005) Régionalisation des scénarios de changement climatique. Environnement, Risque et Santé, vol.4, n°2, 89-94

Eric MARTIN

Martin, Eric, 43 years old, Ingénieur en chef des Ponts et Chaussées, Docteur and HDR of Université Paul Sabatier, Toulouse. Head of research team at Groupe de météorologie à moyenne échelle of GAME since 2004. Reasearcher, then head of Centre d'études de la neige (CEN) of GAME from 1994 to 2004. Co-author of IPCC fourth assessment report.

Martin E., Giraud G., Lejeune Y., Boudart G. 2001. Impact of climate change on avalanche hazard. Annals of glaciology, 32, 163, 167.

Martin, E. and P. Etchevers, 2005: Impact of climatic change on snow cover and snow hydrology in the French Alps. In: Global Change and Mountain Regions (A State of Knowledge Overview) [Huber U. M., H. K. M. Bugmann and M. A. Reasoner (eds.)], Springer, Dordrecht, pp.235-242.

Alcamo, J., J.M. Moreno, B. Novaky, M. Bindi, R. Corobov, R.J.N. Devoy, C. Giannakopoulos, E. Martin, J.E. Olesen, A. Shvidenko, 2007: Europe. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, C.E. Hanson, P.J. van der Linden, Eds., Cambridge University Press, Cambridge.

Pierre ETCHEVERS

Etchevers, Pierre, 38 years old, Ingénieur en chef des Ponts et Chaussées. Head of Centre d'études de la neige (CEN) of GAME since 2004. Researcher at CEN from 1996 to 2003.

Etchevers P., Golaz C., Habets F. and Noilhan J. (2002) : Impact of a climate change on the Rhone river catchment hydrology. J. Geophys. Res., 107 (D16), 10.1029/2001JD000490.

Strasser U., Etchevers P. and Lejeune Y. (2002) : Inter-comparison of two snow models with different complexity using data from an alpine site. Nordic Hydrology, 33(1), 15-26.

Etchevers P., E. Martin, R. Brown, C. Fierz ,Y. Lejeune, E. Bazile, A. Boone, Y.-J. Dai, R. Essery, A. Fernandez , Y. Gusev, R. Jordan, V. Koren, E. Kowalczyk, R. D. Pyles, A. Schlosser, A. B.Shmakin, T. G. Smirnova, U. Strasser, D. Verseghy, T. Yamazaki, Z.-L. Yang (2002) : SnowMIP, an intercomparison of snow models: first results. Proceedings of the International Snow Science Workshop (ISSW 2002), October 2002, Penticton, British Columbia, Canada.

Gerbaux, Genthon C., Etchevers P., Vincent C., Dedieu J.-P. (2005) : Surface mass balance of glaciers in the French Alps : distributed modeling and sensitivity to climate change. Accepted by Journal of Glaciology.

Lejeune Y., P. Wagnon, L. Bouilloud, P. Chevallier, P. Etchevers, E. Martin, J. –E. Sicart, F. Habets (2007) Melting of snow cover in a tropical mountain environment in Bolivia : processes and modelling. Accepted by Journal of Hydro-meteorology.

Yves DURAND

Durant, Yves, 57 years old, Ingénieur en chef des Ponts et Chaussées. Since 1991, deputy head of Centre d'études de la neige (CEN) of GAME. From 1985 to 1989, researcher in data assimilation at Météo-France (Paris). Yves Durand has a long experience in numerical analyses of meteorological fields which he has principally used for the automatic determination of small-scale fields in mountainous areas with several international publications. He manages at CEN the team "Meteorology and Mountains"; which works also on the snowdrift experiments, remote sensing and downscaling operators. He supervises the daily numerical products at different spatial scales which includes meteorological and snow oriented products as avalanche risks, extreme events, precipitation and melting amounts evaluation.

Durand, Y., G. Guyomarc'h and L. Mérindol. 2001 : Numerical Experiments of Wind Transport over a Mountainous Instrumented Site. (Part. 1: Regional scale), Ann. Glaciol., 32, 187-195. IGS meeting, Innsbruck May 2000, Austria.

Durand, Y., Guyomarc'h, G., Mérindol L., Corripio, J.G., 2004. 2D numerical modelling of surface wind velocity and associated snowdrift effects over complex mountainous topography, Ann. Glaciol., 38, 59-71.

Durand, Y., Guyomarc'h, G., Mérindol, L., Corripio, J.G., 2005. Improvement of a numerical snow drift model and field validation, Cold Region Science and technology (CRST), Vol 43, Issues 1-2,Nov. 2005, pp 93-103.

Svanbjorg H. Haraldsdottir, Haraldur Olafsson, Durand Y., Giraud G. and Mérindol L., 2004. "A system for prediction of avalanche hazard in the windy climate of Iceland", Ann. Glaciol., Vol 38, 319-325.

Corripio, J.G., Durand, Y., Guyomarc'h, G., Mérindol, L., Lecorps, D., Pugli,se P., 2004. Land-based remote sensing of snow for the validation of a snow transport model. Cold Regions Science and Technology, 39, 93-104.

Laurent LI

Li, Laurent, 43 years old, senior scientist of CNRS working in the LMD since more than 20 years. He got his Ph.D degree from the University of Paris in 1990. The research activities of Laurent Li cover a large spectrum of climate and environmental resources, including atmospheric general circulation, coupling of ocean and atmosphere, scale interaction in the climate system, and impacts of climate change. He is author or co-author of more than 50 publications in these fields. Laurent Li is now a member of the MedCLIVAR scientific steering committee, team leader of the regional climate and Mediterranean climate inside LMD. He is currently sub-project leader of two EU climate projects devoted respectively to the Mediterranean region (CIRCE) and Eastern Europe (CLAVIER).

Li, L, A. Bozec, S. Somot, K. Beranger, P. Bouruet-Aubertot, F. Sevault, M. Crepon, 2006: Regional atmospheric, marine processes and climate modelling. In "Mediterranean climate variability and predictability" edited by P. Lionello, P. Malanotte-Rizzoli and R. Boscolo, Elsevier, Amsterdam, pp. 373-397.

d'Orgeval, T., J. Polcher and L. Li, 2006: Uncertainties in modelling future hydrological change over West Africa. Climate Dynamics, 26, 93-108.

Li, L., A. Bozec, S. Somot, 2006: Modelling regional-scale climate change of the Mediterranean. Exchanges CLIVAR newsletter, No. 37 (vol. 11, no.2) pp. 24-27.

Li, Z.X., 2006: Atmospheric GCM response to an idealized anomaly of the Mediterranean sea surface temperature. Climate Dynamics, 27, 787-813.

Goubanova, K., and L. Li, 2007: Extremes in temperature and precipitation around the Mediterranean basin in an ensemble of future climate scenario simulations. Global and planetary change, 57, 27-42.

Laurent TERRAY

Terray, Laurent, 47 years old, senior scientist at CERFACS. Dr. Laurent Terray is active in the field of climate modeling for more than 15 years, working on ENSO, on the tropical Pacific Ocean, as well as on climate variability over the North Atlantic and Europe. He is now studying anthropogenic climate change and related impacts at global to regional scales using innovative downscaling techniques. He has coordinated modeling research activities on these themes within the CLIVAR French program PNEDC (Programme National d'Etude de la Dynamique du Climat) and has been involved in many European projects (e.g. PREDICATE, ENSEMBLES and DYNAMITE). Dr Terray is also a member of various scientific committees (e.g. CLIVAR Atlantic Implementation Panel, LEFE/EVE scientific panel, former member of the ANR-VMC panel).

Boé J., L. Terray, F. Habets and E. Martin, 2006: A simple statistical-dynamical downscaling scheme based on weather types and conditional resampling J. Geophys. Res., 111, D23106.

Caminade C. and L. Terray, 2006: Influence of increased greenhouse gases and sulphate aerosols concentration upon diurnal temperature range over Africa at the end of the 20th century Geophys. Res. Lett., 33, L15703.

Boé J., L. Terray, F. Habets and E. Martin, 2007: Statistical and dynamical downscaling of the Seine basin climate for hydro-meteorological studies. Int. J. Clim., 27(12), 643-1655, doi:10.1002/joc.1602.

Boé J. and L. Terray, 2008: A weather type approach to analysing winter precipitation in France: twentieth century trends and influence of anthropogenic forcing J. Clim., in press.

Boé J. and L. Terray, 2008: Uncertainties in summer evapotranspiration changes over Europe and implications for regional climate change Geophys.Res.Lett., 35, L05702, doi:10.1029/2007GL032417.

Vincent JOMELLI

Jomelli, Vincent, 39 years old, Geomorphologist chargé de recherches (CR1) at CNRS Laboratoire de Géographie Physique de Meudon since 1998, on leave at IRD till 31 August 2008 at Unité de Recherche 032 GREAT ICE. Professeur associé at Université Laval (Québec, Canada), Département de Géographie.

Jomelli, V., Déqué, M., Brunstein, D., Grancher, D. (2007). Probabilités d'occurrence des coulées de débris de versant dans les Alpes françaises au 21em siècle estimées à partir des sorties du modèle ARPEGE. Géomorphologie, 4, 283-292.

Jomelli, V., Brunstein, D., Grancher, D., and Pech, P. (2007). Is the response of hill slope debris flows to recent climate change univocal? A case study in the Massif des Ecrins (French Alps). Climatic Change, 85, 119-137.

Jomelli, V., Delval, C., Grancher, D., Brunstein, D., Escande, S., Hétu, B., Filion, L. and Pech, P., (2007). Probabilistic analysis of snow avalanches and climate relationships in the French Alps since the 1980's. Cold Region Science and Technology, 47, 180-192.

Jomelli, V., Pech, P., Chochillon, C. and D. Brunstein (2004). Geomorphic variations of debris flows and recent climatic change in the French Alps. Climatic Change, (64), 77-102.

Jomelli, V., Chochillon, C., Brunstein, D et P. Pech (2003). Hillslope debris flows frequency since the beginning of the 20th century in the French Alps. Debris flow hazards mitigation; Rickenmann &Chen (ed), Millpress Rotterdam, 127-137.

Médaille de Bronze of CNRS section 31 in 2004

Prix de la recherche in 2006, mention Ministère de la Recherche, Principal investigator of the project « Le Petit Age glaciaire dans les Andes tropicales : approche pluridisciplinaire », in collaboration with D. Brunstein, V. Favier., D. Grancher, G. Hoffmann, P. Naveau, A. Rabatel, F. Vimeux

Frédéric LEONE

Leone, Frédéric, 39 years old, Geograph, Enseignant-chercheur at Département de Géographie-Aménagement de l'Université Montpellier 3, Member of GESTER (Gestion des Territoires et des Risques, Université Montpellier III) laboratory. Maître de conférences since 1996 (Université des Antilles-Guyane / Université Montpellier III).

Leone F. (1996) – Concept de vulnérabilité appliqué à l'évaluation des risques générés par les phénomènes de mouvements de terrain – Coll. Documents du BRGM, n°250, Ed. B.R.G.M., Orléans, 286 p.

Leone F., Asté J.P., Leroi E. (1996) – Vulnerability assessment of elements exposed to mass-movement : Working toward a better risk perception – In: Senneset K. (ed.): Landslides, Ed. Balkema, Rotterdam, pp. 263-269.

Leone F. & Velasquez E. (2002) – La catástrofe del deslizamiento de la Josefina (Ecuador, 1993) : algunas enseñanzas sobre la vulnerabilidad – In : José Lugo Hubp & Moshe Inbar (compiladores) : Desastres Naturales en América Latina – Ed. Fondo de Cultura Económica, Mexico, pp. 429-445.

Leone F. (2004) – Une approche quantitative de la cartographie des risques naturels : application expérimentale au patrimoine bâti de la Martinique (Antilles françaises) – Géomorphologie : relief, processus, environnement, n°2, pp. 117-124.

Leone F., Vinet F., Denain J.C., Bachri S. (2007) – Développement d'une méthodologie d'analyse spatiale des destructions consécutives au tsunami du 26 décembre 2004 (Banda Aceh, Indonésie). Premiers résultats pour l'élaboration de futurs scénarios de risque – Géocarrefour 20 p.

Daniel BRUNSTEIN

Brunstein, Daniel, 44 years old, ingénieur de recherche at CNRS (LGP-UMR8591)

F. Costard, E. Gautier, D. Brunstein, J. Hammadi, A. Fedorov, D. Yang and L. Dupeyrat (2007), Impact of the global warming on the fluvial thermal erosion over the Lena River in central Siberia, Geophys. Res. Lett., 34, (in press) doi:10.1029/2007GL030212

Jomelli V., Brunstein D., Grancher D. and P. Pech (2007). Is the response of hill slope debris flows to recent climate change univocal? A case study in the Massif des Ecrins (French Alps). Climatic Change, online, doi:10.1007/s10584-006-9209-0.

Jomelli, V ., Grancher, D., Brunstein, D. Solomina, O., (2007). Recalibration of the Rhizocarpon growth curve in Cordillera Blanca (Peru) and LIA chronology implication. Geomorphology, Article in press, doi:10.1016/j.geomorph.2007.02.021.

Ruelland D., Billen G., Brunstein D., Garnier J. (2007). SENEQUE: A multi-scaling GIS interface to the Riverstrahler model of biogeochemical functioning of river systems. Sci. Total Environ, 375 (1), p.257-273, doi:10.1016/j.scitotenv.2006.12.014

Lavigne F., Paris R., Wassmer P., Gomez C., Brunstein D., Grancher D., Vautier F., Sartohadi J., Setiawan A., Syahnan, Gunawan T., Fachrizal, Waluyo B., Mardiatno D., Widagdo A., Cahyadi R., Lespinasse N., Mahieu L. (2006). Learning from a major disaster (Banda Aceh, December 26th, 2004): a methodology to calibrate simulation codes for tsunami inundation models. Zeitschrift fur Geomorphologie, 146, 253-265.

2006 : prix de la Recherche « le petit Age de Glace dans les Andes » (see Vincent Jomelli)

Delphine GRANCHER

Grancher Delphine ,29 years old , ingénieur d'étude at CNRS (LGP)

Jomelli, V., Grancher, D., Naveau, P., Cooley, D. (2007). Assessment study of lichenometric methods for dating surface. Geomorphology, 86, 131-143.

Jomelli V., Brunstein D., Grancher D. and P. Pech (2007). Is the response of hill slope debris flows to recent climate change univocal? A case study in the Massif des Ecrins (French Alps). Climatic Change,85, 119-137, online, doi:10.1007/s10584-006-9209-0.

Naveau P., Jomelli V., Cooley D., Grancher D. Rabatel A. (2007).Modeling uncertainties in lichenometry studies with an application: The Tropical Andes (Charquini Glacier in Bolivia). Arctic, Antarctic and Alpine Research Vol39 N°2 pp 277-285.

Jomelli V., Delval C., Grancher D., Brunstein D., Escande S., Hétu B., Filion L. and Pech P. (2006). Probabilistic analysis of snow avalanches and climate relationships in the French Alps since the 1980's. Cold Region Science and Technology. Volume 47, 180-192. Issues 1-2, 1 January 2007, Pages 180-192, http://dx.doi.org/10.1016/j.coldregions.2006.08.003

Grancher D., Bel L., Vautard R., (2005) Estimation de champs de pollution par adaptation statistique locale et approche non stationnaire.Journal Européen des Systèmes automatisés Volume 39 n°4/2005 p475-792 Hermes

2006 : prix de la Recherche « le petit Age de Glace dans les Andes » (see Vincent Jomelli)

Hubert GALLEE

Hubert Gallée, 54 years old, directeur de recherches at CNRS, has been head of regional climate modeling group at Université Catholique de Louvain (Belgium), where he developed the MAR RCM and applied it to climate studies of Antarctica and Greenland. Moving to Grenoble in 1997, he collaborated with CEN by developing a wind driven snow transport model, coupled to a snow model. He worked then at LTHE (Grenoble) where he studied western Africa climate. He is has been working at LGGE since 2002, where his main research subject is again Antarctica.

Fettweis, X., J.-P. Van Ypersele, H. Gallée, F. Lefebre and W. Lefebvre, 2007: The 1979–2005 Greenland ice sheet melt extent from passive microwave data using an improved version of the melt retrieval XPGR algorithm, Geophys. Res. Lett., 34, L05502, doi:10.1029/2006GL028787.

Gallée, H., W. Moufouma-Okia, P. Bechtold, O. Brasseur, I. Dupays, P. Marbaix, C. Messager R. Ramel and T. Lebel, 2004 : A high resolution simulation of a West African rainy season using a regional climate model. Journal of Geophysical Research 109, D05108, doi 10.1029/2003JD004020.

Gallée, H., V. Peyaud and I. Goodwin, 2005: Temporal and spatial variability of the Antarctic Ice Sheet Surface Mass Balance assessed from a comparison between snow stakes measurements and regional climate modeling. Annals of Glaciology 41, 17-22.

Messager, C., H. Gallée, O. Brasseur, B. Cappelaere, C. Peugeot, L. Séguis, M. Vauclin, R. Ramel, G. Grasseau, L. Léger and D. Girou, 2006: Influence of observed and RCM-simulated precipitation on the water discharge over the Sirba basin, Burkina Faso/Niger. Climate Dynamics, 10.1007/s00382-006-0131-y.

Ramel, R., H. Gallée and C. Messager, 2006: On the northward shift of the West African Monsoon. Climate Dynamics doi 10.1007/s00382-005-0093-5.

Partner's involvement in other projects **(cf. § 1.8.3)**

Partner 1 GAME	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Allocated bud-gets	Proposal title	Name Principal Inverstigator	Start-End of the project
	Déqué Somot Braun	14 14 5	FP6 98 k€	ENSEMBLES	P. Van Linden	2004-2009
	Déqué Braun Somot	10 10 10	FP6 122 k€	CECILIA	T. Halenka	2006-2009
	Déqué Somot	6 8	FP6 100 k€	CIRCE	A. Navarra	2007-2011
	Déqué Braun	1 1	FP7 93 k€	METAFOR	E. Guilyardi	2008-2011
	Déqué	1	ANR-VMC 4 k€	CLIMATOR	N. Brisson	2007-2010
	Déqué Somot Martin	7.2 19.8 3.6	ANR-VMC 196 k€	MEDUP	V. Ducroq	2008-2010
	Déqué Martin	1 3.6	MEDAD-GICC 8k€	REXHYSS	A. Ducharne	2006-2009
	Martin	3.6	ANR-VMC 15 k€	VULCAIN	Y. Caballero	2007-2010
	Martin	9	ANR-VMC 100 k€	VULNAR	P. Ackerer	2008-2010
	Etchevers Durand	0.5 0.5	FP7 46 k€	ACQWA	M. Beniston	2008-2012

Partner 2 LMD	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Allocated budgets	Proposal title	Name Principal Inverstigator	Start-End of the project
	Li	12	FP6 200 k€	CLAVIER	D. Jacob	2006-2009

	Li	12	FP6 100 k€	CIRCE	A. Navarra	2007-2011
	Li	10	ANR 54 k€	IRCAAM	H. Douville	2007-2010

Partner 3 CERFACS	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Allocated budgets	Proposal title	Name Principal Inverstigator	Start-End of the project
	Terray Maisonnave	12 12	FP6 250 k€	ENSEMBLES	P. Van Linden	2004-2009
	Terray Pagé	8 12	ANR-VMC 100 k€	CLIMATOR	N. Brisson	2007-2010
	Terray Pagé	1 1	ANR-VMC 3 k€	VALIDATE	J.F Soussana	2008-2011
	Terray Pagé	4 6	MEDAD-GICC 100 k€	REXHYSS	A. Ducharne	2006-2009
	Pagé	1	MEDAD-GICC 16 k€	ACCIES	P. Sabatier	2006-2009

Partner 4 LGP	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Allocated budgets	Proposal title	Name Principal Inverstigator	Start-End of the project
	Jomelli	7.2	ANR CLIMAT 800 k€	Escarcel	Guiot	2006-2009
	Jomelli Grancher Brunstein Leone	7.2 7.2 3 7.2	FP7 1700 k€	Acqwa	Beniston	2008-2010
	Brunstein	24	ANR-VMC 179 k€	CLIMAFLU	Costard	2008-2011
	Leone	7.2	FP7 4000 k€	MIA-VITA	Thierry	2008-2010

Partner 5 LGGE	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Allocated budgets	Proposal title	Name Principal Inverstigator	Start-End of the project
	Gallée	14	LEFE	CHARMANT	G. Krinner	2008-2010
	Gallée	6	FP6	ENSEMBLES	P. Van Linden	2004-2009

Other proposals under evaluation

Partner 1 GAME	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Expected grants	Proposal title	Name Principal In-verstigator
	Déqué Braun	1 2	FP7 10 k€	IS-ENES	S. Joussaume
	Somot	2	ANR-VMCS 11.5 k€	VURCA	J.C. Hourcade

Partner 2 LMD	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Expected grants	Proposal title	Name Principal In-verstigator

Partner 3 CERFACS	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Expected grants	Proposal title	Name Principal In-verstigator
	Terray	24	FP7 250 k€	IS-ENES	S. Joussaume
	Terray	6	FP7 130 k€	COMBINE	M. Giorgetta

Partner 4 LGP	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Expected grants	Proposal title	Name Principal In-verstigator
	Jomelli Grancher Brunstein	9.8 7.4 4.2	ANR Blanc	Coherence	Jomelli

Partner 5 LGGE	Name of the person involved in the project	Man.month	Name call for proposals Other fundings from different organisms Expected grants	Proposal title	Name Principal In-verstigator
	Gallée	11	FP7	COMBINE	M. Giorgetta
	Gallée	3	FP7	ICE2SEA	D. Vaughan

List of acronyms

ALADIN Aire Limitée, Adaptation Dynamique pour la coopération Internationale. Reginal model used by GAME. It is a limited-area version of the ARPEGE GCM

AR4 Assessment Report 4, see IPCC

ARPEGE Action de Recherche Petite Echelle Grande Echelle. GCM used by GAME to drive ALADIN at its lateral boundaries. It uses the same dynamical core and physical parameterizations as ALADIN.

CECILIA Central and Eastern Europe Climate Change Impact and VulnerabiLIty Assessment, European FP6 project based on dynamical and statistical downscaling scenarios over central and eastern Europe. The modeling strategy here is double nesting with 10 km resolution over small domains.

CEN Centre d'Etude de la Neige. Part of GAME located in Grenoble and dedicated to snow research

CMIP3 Coupled Model Intercomparison Project 3, see IPCC

CROCUS one-dimensional snow pack model

ENSEMBLES ENSEMBLE-based Predictions of Climate Changes and their Impacts, European FP6 project including dynamical and statistical downscaling scenarios over Europe

ECMWF European Center for Medium-range Weather Forecasts, has provided a 44-year reanalysis (1958-2001) widely used in Europe

GCM General Circulation Model

GICC Gestion et Impacts du Changement Climatique, French research program of the ministry of environment

GIS Geographical Information System

IMFREX IMpact sur la FRéquence des Extrêmes, GICC project devoted to extremes phenomena in scenarios over France

IPCC Intergovernmental Panel on Climate Change

ISBA Interface Sol Biosphère Atmosphere. The surface scheme of ALADIN. ISBA-ES means ISBA explicit snow

LMDZ Regional model used by LMD. Z means zoom possibility

LSC Large-Scale Circulation

MAR Modèle Atmosphérique Régional. Regional model used by LGGE

ONERC Observatoire National sur les Effets du Réchauffement Climatique

PDF Probability Distribution Function

PRUDENCE Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects, European FP5 project devoted to dynamical downscaling scenarios over Europe

RCM Regional Climate Model

SAFRAN Système d'Analyse fournissant des renseignements atmosphériques à la neige. High resolution (8km) analysis system over France. Another version produces higher resolution data for Alpine sub-regions

SDM Statistical Downscaling Model

SST Sea Surface Temperature

STARDEX STAtistical and Regional dynamical Downscaling of EXtremes for European regions, European FP5 project devoted to extremes phenomena in scenarios over Europe

WCRP World Climate Research Program, depends on WMO