***STAtistical and Regional Dynamical downscaling of EXtremes for European regions***

***STARDEX***

***Description of Work***

**15 June 2001**

# Contents

## LIST OF TABLES



## LIST OF FIGURES

# LIST OF PARTNERS

| | | |
|---|---|---|
| 1 | UEA | University of East Anglia, UK |
| 2 | KCL | King’s College London, UK |
| 3 | FIC | Fundación para la Investigación del Clima, Spain |
| 4 | UNIBE | University of Bern, Switzerland |
| 5 | CNRS | Centre National de la Recherche Scientifique, France |
| 6 | ARPA-SMR | Servizio Meteorologico Regional, ARPA-Emilia Romagna, Italy |
| 7 | ADGB | Atmospheric Dynamics Group, University of Bologna, Italy |
| 8 | DMI | Danish Meteorological Institute, Denmark |
| 9 | ETH | Eidgenössische Technische Hochschule, Switzerland |
| 10 | FTS | Fachhochschule Stuttgurt – Hochschule für Technik, Germany |
| 11 | USTUTT-IWS | Institut für Wasserbau, Germany |
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| | DNMI | Norwegian Meteorological Institute, Norway |
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## 1. Project Summary

The climate of the 21st century is likely to be significantly different from that of the 20th because of anthropogenically-induced climate change. The Kyoto protocol and future initiatives, together with actions taken by the EU, are expected to reduce the impacts of the changes, but significant changes will still occur. These changes will be perceived by European citizens mostly through increases in some types of extreme weather. STARDEX aims to provide scenarios of expected changes in the frequency and intensity of extreme events (such as heavy precipitation and resultant flooding and high temperatures) which are likely to have an impact on human lives and activities and on the environment. Climate change scenarios, particularly those for extremes, are needed for all aspects of future design (e.g., water resources, agriculture, irrigation, storm and land drainage, road, railway and building design and other sectors such as tourism) where the weather and climate are key determinants of everyday life. In all these aspects there is a clear European-wide need for more reliable, high-resolution scenarios of extremes. STARDEX will not be making predictions, but providing information on the likely changes in extremes. If work of this kind is not undertaken, future designs will not be able to incorporate the latest information about changes in extreme climate in the future.

STARDEX will achieve its aims by a rigorous and systematic intercomparison of the three main downscaling methods (statistical, dynamical and statistical-dynamical) that are used to construct scenarios of extremes at the time and space scales where they are most needed. STARDEX will identify the more robust downscaling techniques and apply them to provide reliable and plausible future scenarios of temperature and precipitation-based extremes for selected European regions for the 2071-2100 timeframe. The extreme scenarios will incorporate three forms of uncertainty related to the specific downscaling method, different future emission paths and inter- and intra-model variability. To achieve these aims, STARDEX will develop standard observed and climate model data sets and a diagnostic software tool for calculating a standard set of extreme statistics across Europe. Two of the major climate models in Europe (HadCM3 and ECHAM4/OPYC) will be extensively validated, with the particular emphasis on extremes. The intercomparison of downscaling methods will take place using observed climate data from the second half of the 20th century. Finally, recent extremes across Europe will be analysed. What were their causes and impacts? Was anthropogenic climate change a factor? What can be learned from the recent past? The analysis of the recent past will bring together representatives from the re-insurance industry and the climate modelling and climate impact communities in an expert advisory panel.

The impacts of STARDEX will be improved methodologies for the development of scenarios of extremes, with recommendations as to which are best for different regions across Europe and for different variables. The various sectors listed above will be able to find off-the-shelf scenarios of extremes relevant to their business, incorporating all the various uncertainties. The scenarios will be used for many aspects of design (e.g., modification of dam design criteria, agricultural potential and alteration to insurance premiums) where extremes of weather are crucial determinants. The results will be made available through standard methods of scientific publications and reports, conferences and the World-wide Web.

# 2. Scientific/technical Objectives and Innovation

## 2.1 Scientific objectives

**Introduction**

Changes in the frequency and intensity of extreme events are likely to have more of an impact on the environment and human activities than changes in mean climate. Losses of life and very high economic damages have, for example, been experienced during recent flooding events in the last two years in Italy, Switzerland, France, the UK and across central Europe. The severe heatwaves which have occurred in the eastern Mediterranean in recent summers illustrate the risks to human health from short-duration temperature extremes. A vital question for Europe is, therefore, whether such events will occur more frequently in the future. For many socio-economic and environmental sectors in Europe there is a clear need for more reliable, high-resolution scenarios of extremes. This is the problem which STARDEX aims to address.

**General objectives**

- To rigorously and systematically inter-compare and evaluate statistical, dynamical and statistical-dynamical downscaling methods for the reconstruction of observed extremes and the construction of scenarios of extremes for selected European regions.
- To identify the more robust downscaling techniques and to apply them to provide reliable and plausible future scenarios of temperature and precipitation-based extremes for selected European regions.

**Measurable objectives**

1. Development of standard observed and climate model simulated data sets, and a diagnostic software tool for calculating a standard set of extreme event statistics, for use by all partners.
2. Analysis of recent trends in extremes, and their causes and impacts, over a wide variety of European regions.
3. Validation of HadCM3 and ECHAM4/OPYC3 climate model integrations, particularly for extremes.
4. Inter-comparison of improved statistical, dynamical and statistical-dynamical downscaling methods using data from the second half of the 20$^{th}$ century and identification of the more robust methods.
5. Development of scenarios, particularly for extremes, for the late 21$^{st}$ century using the more robust statistical, dynamical and/or statistical-dynamical downscaling methods.

**Specific objectives**

1. To focus on an agreed, standard set of daily temperature extremes (e.g. percentiles of daily maximum/minimum temperature, frost severity and duration indices and a heatwave duration index) and daily precipitation extremes (e.g. maximum length of dry/wet spells, magnitude of the 90$^{th}$ percentile, percentage of rain falling on days with amounts above

the 90$^{th}$ percentile) together with derived indices/parameters (e.g. thermal discomfort and fire hazard indices, extreme runoff events).

2. To focus on specific regions of Europe, selected on the basis of the availability of data and the expertise of the partners, ensuring that the selected case-study regions reflect the range of European climatic regimes and that the size/location of each region is appropriate for the extreme being studied (thus these regions will encompass the British Isles, the Alps, the Mediterranean, Scandinavia and Germany).

3. To use a consistent approach (in terms of regions, observed and climate model data inputs, variables and statistics studied and time periods) for all analyses and case studies in order to allow rigorous and systematic evaluation and *direct* inter-comparison of the results.

4. To analyse observed data series for the second half of the 20$^{th}$ century from specific regions of Europe in order to identify trends in the magnitude and frequency of occurrence of extremes (and, for specific events, their losses in life and financial costs) and to investigate whether these changes are related to changes in other climatic variables (i.e. potential predictor variables derived primarily from NCEP Reanalysis data, such as large-scale and regional objective circulation indices and patterns, including the North Atlantic Oscillation, measures of atmospheric humidity and stability and sea surface temperatures).

5. To analyse output from the HadCM3 and ECHAM4/OPYC3 GCMs, and RCMs driven both by these two GCMs and by Reanalysis data, focusing on their ability to simulate temperature and precipitation-based extremes (including their magnitude, frequency of occurrence and trends) and potential predictor variables (including their inter-relationships and relationships with surface climate).

6. To improve existing circulation-based statistical downscaling methods (including methods based on probabilistic weather generators, canonical correlation, multiple regression, neural networks, fuzzy rules and analogue approaches) so that they are able to reproduce observed extremes. This will include the incorporation of additional predictor variables [such as humidity and stability-related parameters (e.g. low-level thermal advection) and sea surface temperatures] in order to address the problem of stationarity (i.e. the underlying assumption of statistical downscaling that observed large-scale/surface climate relationships remain valid under a changed climate).

7. To calibrate and validate improved 'regional' statistical downscaling methods using predictor variables derived from NCEP (1958-2000) Reanalysis data (for calibration and validation under 'perfect' conditions, e.g. can past changes in extremes be explained?) and from HadCM3 and ECHAM4/OPYC3 integrations (that include both anthropogenic and natural forcing) for the present day (in order to assess the effects of climate model biases).

8. To compare the results for specific European regions with output from RCMs (including statistical-dynamical simulations) driven by the same underlying GCMs (i.e. HadCM3 and ECHAM4/OPYC3), with RCMs driven by Reanalysis data, and with results from a two-step analogue approach to statistical downscaling applied European-wide (for a network of 400-500 stations).

9. To apply the more robust statistical, dynamical and/or statistical-dynamical downscaling methods [identified in 7 and 8 on the basis of (i) present-day validation studies, (ii) inter-comparison of the scenarios obtained by different methods, and (iii) analysis of the ability of the GCMs/RCMs to reproduce the statistics and inter-relationships of the observed

predictor variables] to HadCM3 and ECHAM4/OPYC3 (and their associated RCMs) integrations for the end of the 21st century to provide scenarios of extreme events and the associated impacts (such as floods, low-river flow, fire hazard and thermal discomfort) for European regions and to assess the uncertainties associated with these scenarios.

10. To use these scenarios to identify changes in extremes, to investigate whether these changes are in accordance with recent observed changes and to consider their potential impacts in terms of losses of life and financial costs (based on the impacts of observed changes).

11. To ensure that the needs of the European climate impacts community for scenarios of extremes are taken into account, that output from the most recent climate model simulations is available for use in the project and that the work is subject to ongoing peer review - by bringing together representatives of the stakeholder (e.g. re-insurance), climate modelling and climate impacts communities in an expert advisory panel.

12. To ensure wide dissemination of the project results to stakeholders, the scientific community and the public through the project web site and the production of reports, brochures, information sheets and scientific papers.

## 2.2 Innovation

For many European Union countries, climatic change from whatever cause is most evident, particularly to the public and media, through changing frequencies of extremes. Potential changes in extremes and the ensuing increases/decreases in risk are important for a number of economic sectors (e.g. agriculture, insurance and water resources) (Cramer *et al*., 2000; Karl *et al*., 1999; Beersma *et al*., 2000). While there is a clear need for scenarios of extremes, such scenarios are not readily available at present, mainly because a systematic framework for identifying and evaluating suitable construction methods is lacking (Meehl *et al*., 2000).

GCMs are considered to provide the best basis for estimating future climates that might result from further anthropogenic modification of the atmospheric composition. However, output from these models cannot be widely or directly applied in many impact studies because of their relatively coarse spatial resolution. The mismatch in scales between model resolution and the increasingly small scales required by impact analysts can be overcome by downscaling. Two major approaches to downscaling, statistical and dynamical (the latter using physically-based RCMs), have been developed and tested in recent years by a number of different research groups, and shown to offer good potential for the construction of high-resolution scenarios (Hewitson and Crane, 1996; Wilby *et al*., 1998; Giorgi and Mearns, 1999; Zorita and von Storch, 1999). In both cases, however, the focus has been on changes in mean climate rather than on daily extremes and there is considerable scope for further development and refinement of the methodologies.

Statistical downscaling methods are based on the application of relationships identified in the real world, between the large-scale and smaller-scale climate, to climate model output. Thus recent observational studies (such as the ACCORD project funded by the European Union), particularly those investigating links between circulation patterns and surface climate, provide valuable insights. These studies demonstrate that additional predictor variables, such as atmospheric humidity and stability, should be incorporated into statistical downscaling as well as circulation changes (Wilby and Wigley, 2000). Thus a number of major issues have been raised by the observational work, but have not yet been systematically or routinely incorporated into statistical downscaling studies. STARDEX aims to use the expert knowledge gained from observational work to refine the currently-available statistical downscaling techniques and to extend the work to focus on extremes.

Ongoing work funded by the European Union is aimed at improving the current generation of RCMs, focusing on improvements in parameterisations of key processes and increasing the spatial resolution yet further (Jones *et al*., 1995; Giorgi and Marinucci, 1996; Christensen *et al*., 1997; Jones *et al*., 1997; Christensen *et al*., 1998; Machenhauer *et al*., 1998; Noguer *et al*., 1998; Heck *et al*., 2001). Thus the new generation of RCMs should offer more reliable and higher-resolution output than before. However, the performance of RCMs in comparison with statistical downscaling techniques has not been adequately addressed, particularly with respect to extremes (Mearns *et al*., 1999). STARDEX will rigorously and systematically inter-compare and evaluate statistical and dynamical downscaling methods for the reconstruction of observed extremes and the construction of scenarios of extremes for selected European regions. A method of downscaling which incorporates aspects of both these approaches will also be considered, i.e. statistical-dynamical downscaling in which ensemble RCM integrations are performed in order to identify relationships between surface climate and the large-scale GCM patterns (Fuentes and Heimann, 2000; Heimann and Sept, 2000).

While limited inter-comparisons of statistical and dynamical downscaling methods have been undertaken (Kidson and Thompson, 1998; Charles *et al*., 1999; Mearns *et al*., 1999; Murphy, 1999; Murphy, 2000), the proposed STARDEX work has a number of major distinguishing and innovative features:

- the focus will be on daily temperature and precipitation-based extremes, rather than mean climate;
- a consistent approach (in terms of regions, observed and climate model data inputs, variables and statistics studied and time periods) will be taken;
- a regional case-study approach will be used in order to allow detailed assessment at an appropriate high spatial resolution, with the regions selected to represent the full range of climatic conditions across Europe;
- each downscaling method will be tested in a number of different regions and for a number of different extreme indicators;
- the statistical and dynamical downscaling modelling work will be underpinned by detailed analyses of observed data which will lead to the development of improved downscaling methods and provide data for validation; and,
- the involvement of stakeholders and members of the climate impacts community in the project will ensure that the focus is on those extremes which are most relevant to the insurance, water-industry and other economic sectors.

STARDEX will consider a range of temperature and precipitation-based extreme indicators, including a number which have recently been used in, or recommended for use in, international studies of observed changes in extremes (Karl *et al*., 1999; Easterling *et al*., 2000; Frich *et al*., 2001). Many of these indicators are based on percentiles determined by the distributions of the raw data rather than absolute thresholds and are thus more appropriate for inter-regional comparisons. In order to ensure that all indicators are calculated in a consistent and efficient manner, a diagnostic software tool will be developed by one of the partners and made publicly available. Other derived indices, such as thermal discomfort and fire hazard indices will require the construction of consistent multi-variate scenarios: an issue often neglected in statistical downscaling. The need to provide consistent multi-site scenarios will also be addressed.

STARDEX will make use of data sets and techniques derived from other sectors and sciences which have not previously been used for climatic applications. For example, a data base of damages (losses of life and financial costs) produced by the re-insurance industry will be used to investigate the impacts of specific extreme events. Neural networks have previously been used for statistical downscaling (Hewitson and Crane, 1996; Zorita and von Storch, 1999) and will be further tested and evaluated in STARDEX. However, the particular methods to be explored will include support vector neural networks (Vapnik, 1998) which represent the current state-of-the-art in statistical pattern recognition and non-linear regression. They have produced very impressive results in a range of real-world tasks, but have not yet been applied to environmental problems such as downscaling. The use of neural networks to model conditional densities will also be investigated. To date, this approach has only been used in one small-scale, but promising, climate-related case study (Williams, 1998).

The STARDEX management structure and work plan are designed to ensure that a consistent approach is taken for all analyses. This will allow the *direct* inter-comparison of results, across different regions, extreme indicators and methods. For example, dynamical and statistical downscaling models will both be evaluated using Reanalysis data in the first instance. Thus uncertainties due to methodological problems can be quantified and inter-compared for the two different approaches, without having to worry about the additional influences of errors in the underlying GCMs. These will be explored separately, using the same GCM output to drive the RCMs and as predictor variables in the statistical downscaling models. Thus, the STARDEX project will provide a more rigorous and systematic investigation of statistical and regional dynamical downscaling of European extremes than has previously been undertaken for any area of the world.

# 3. Project Workplan

## 3.1 Introduction

The 12 specific objectives of STARDEX (see Section 2.1) will be achieved through five thematic workpackages:

- WP1: Data set development, co-ordination and dissemination (Specific objectives 1-3, 11 and 12).
- WP2: Observational analysis of changes in extremes, their causes and impacts (Specific objective 4).
- WP3: Analysis of GCM/RCM output and their ability to simulate extremes and predictor variables (Specific objective 5).
- WP4: Inter-comparison of improved downscaling methods with emphasis on extremes (Specific objectives 6-8).
- WP5: Application of the more robust downscaling techniques to provide scenarios of extremes for European regions for the end of the 21st century (Specific objectives 9 and 10).

In order to rigorously and systematically inter-compare and evaluate statistical, dynamical and statistical-dynamical downscaling methods, a regional case-study approach will be followed in all STARDEX WPs. The case studies will be selected from areas in which at least one of the partners has substantial expertise and will encompass the British Isles, the Alps, the Mediterranean, Scandinavia and Germany. Adopting a consistent approach to the case studies is a major goal of STARDEX. Thus WP1 will ensure that standard data sets are available to all partners working in each case-study region.

A standard set of temperature and precipitation extremes, based on indicators recommended by a recent international meeting, will be used for all case studies (Table 1). The choice of extremes will be guided, in part, by the problems of statistical uncertainty and sample size. Large differences in extremes may be present between different data sets/methods, but may not be identifiable as statistically significant (Frei and Schär, 2001). Thus, relatively moderate definitions of extremes will be adopted to ensure sufficient sample size.

***Table 1: Proposed standard indicator set of temperature and precipitation extremes relative to the 1961-90 period (based on Karl et al., 1999; Frich et al., 2001).***

| *Temperature extremes* | *Precipitation extremes* |
|---|---|
| • Daily measures of Tmax/Tmin/Tday using 10th/90th percentiles<br>• Diurnal temperature range<br>• Intra-annual extreme temperature range<br>• Number of frost days (Tmin < 0°C)<br>• Frost severity index (percentage of time with Tmin < 0°C)<br>• Growing season length (period between Tday > 5°C for > 5 days and Tday < 5°C for > 5 days)<br>• Heat wave duration index (maximum period > 5 consecutive days with Tmax > 5°C above long-term mean) | • Magnitude of the 90th percentile<br>• Frequency of exceeding 90th percentile (number of days)<br>• Simple daily intensity index (total precipitation/number of rain days)<br>• Maximum length of wet/dry spell<br>• Percentage of precipitation falling on days with rainfall above 90th percentile<br>• No. of days with precipitation ≥ 10 mm<br>• Maximum 5 day precipitation total |

In addition, derived indices and parameters (Table 2) will be used for selected regional case studies (Table 3).

The size/location of each region will depend on the extreme index/parameter being studied. For flooding, for example, the focus will be on the catchment scale in northern/central

Europe, whereas, for drought, the focus will be on southern Europe/the Mediterranean and the area of interest will be larger (e.g. 200-300 km by 200-300 km). However, more than one study region will be used for each extreme and each method, so that the performance of the various downscaling methods in different climatic regimes can be investigated. The indices and parameters listed in Table 2 make additional demands of the downscaling methods: the temperature-based indices require information about variables such as relative humidity and wind (i.e. a requirement for the development of consistent multi-variate scenarios), while consistent multi-site precipitation scenarios are required for the investigation of flooding.

***Table 2: Proposed derived indices and parameters to be used in selected case studies (see Table 3).***

| ***Temperature-based*** | ***Precipitation-based*** |
|---|---|
| • Thermal discomfort index (Thom, 1959; Gawith *et al*., 1999)<br>• Fire hazard index (Piñol *et al*., 1998) | • Runoff (simulated by a robust hydrologic model) |

***Table 3: Proposed regional case studies and their focus (in addition to the standard set of temperature and precipitation extremes which will be produced for all regions, see Table 1).***

| ***Region*** | ***Focus of case study*** |
|---|---|
| Iberian Peninsula and Greece (i.e. western and eastern Mediterranean)<br><br>Partners with particular expertise in this region: UEA, FIC, AUTH | • Thermal discomfort index – data (including wind speed and humidity) available for large Greek cities e.g. Athens, Thessaloniki and Larissa and will be sought for several Spanish cities.<br>• Fire hazard index – data available for Athens, Thessaloniki and the Greek island of Evia and will be sought for the Iberian Peninsula.<br>• Low river flow in selected catchments in Messochora (western Greece) – runoff simulated by a robust hydrologic model.<br>• Regional drought (i.e. at a scale of 200-300 km by 200-300 km). |
| Alps<br><br>Partners with particular expertise in this region: UNIBE, CNRS, ARPA-SMR, ADGB, ETH | • Extreme precipitation.<br>• Identification of homogeneous sub-regions within the Alpine region.<br>• Detailed comparison of a very high-resolution RCM (14 km) coupled to a distributed catchment model with statistical downscaling coupled to a robust hydrologic model. |
| Scandinavia<br><br>Partners with particular expertise in this region: DMI | • Extreme precipitation.<br>• Temperature – frost/growing season duration. |
| Germany<br><br>Partners with particular expertise in this region: FTS, USTUTT-IWS | • Extreme precipitation, including storm events.<br>• Flooding (using extreme diagnostics and hydrological modelling). |
| British Isles<br><br>Partners with particular expertise in this region: UEA, KCL | • Extreme precipitation.<br>• Regional flooding (using extreme diagnostics, e.g. joint probability/frequency of days with heavy snowfall followed by rapid thaw, or intense rainfall on dry/frozen or already saturated ground).<br>• Highly-resolved daily precipitation data for 1961 onwards.<br>• Temperature – frost/growing season duration. |

A standard set of GCM and RCM output from state-of-the-art models and, as far as possible, the most recent simulations, including ensembles, forced by the SRES emissions scenarios developed for the IPCC Third Assessment Report (Nakicenovic and Swart, 2000), will be used for the case studies. It is proposed to use the following two GCMs, which have been recognised as the two most advanced of the current generation of models:

- HadCM3 (Gordon *et al*, 2000; Pope *et al.*, 2000); and,
- ECHAM4/OPYC3 (Wild *et al.*, 1998; Roeckner *et al.* 1999; Stendel *et al.*, 2000).

A major advantage of using these two GCMs is that they have been/will be used to drive RCMs, allowing STARDEX to undertake a fully consistent intercomparison of statistical and dynamical downscaling. HadRM3, for example, has a spatial resolution of 0.44° by 0.44° (approximately 50 km over Europe) compared with 2.5° latitude x 3.75° longitude for HadCM3. Output from RCM simulations (including HadRM3, HIRHAM and CHRM) will be available for the whole of Europe at a resolution of 50 km and (from CHRM) for central Europe, including the Alps, at a resolution of 0.125° by 0.125° (i.e. 14 km).

Members of the STARDEX consortium already have strong links with the HadCM3 and ECHAM4/OPYC3 modelling groups. However, in order to ensure that STARDEX has access to output from the most recent climate model simulations, and to facilitate feedback from the validation studies undertaken in STARDEX WP3, the expert advisory panel will include representatives from these modelling groups. In addition, STARDEX will develop and strengthen existing links with members of the PRUDENCE (Prediction Uncertainties Describing European Climate Change and Effects) consortium. This will allow access to output from new RCM simulations undertaken during the course of PRUDENCE, including statistical-dynamical simulations (Fuentes and Heimann, 2000; Heimann and Sept, 2000).

Individual groups will be responsible for improving and testing specific statistical downscaling methods (see detailed description of WP4 in Section 3.4) in each case-study region. The following generic methodology for statistical downscaling will be adopted in each case:

(i) identification of observed trends and inter-relationships in extremes and potential predictor variables (WP2);
(ii) validation of potential predictor variables (WP3);
(iii) construction/validation of the downscaling model using observed and NCEP Reanalysis data (WP4);
(iv) validation of the downscaling model using GCM/RCM output (WP4); and,
(v) construction of future scenarios (WP5).

In the first instance, the statistical downscaling methods will be judged against the following general principles and criteria:

- reliable and appropriate observational data sets must be available for the predictor(s) and predictand;
- the predictor(s) must be readily available from climate models;
- the predictor(s) must be reliably reproduced by climate models;
- there must be strong predictor/predictand relationships;
- ideally, these relationships should be supported by an understanding of the underlying physical processes; and,
- the extent to which relationships may have changed in the past, and may change in the future, must be considered.

All partners will be involved in the evaluation of the different statistical downscaling methods (WP4), comparison with dynamical and statistical-dynamical downscaling methods (WP4) and evaluation of the future scenarios (WP5). The regional case-study approach will be complemented by a European-wide analysis in which a two-step analogue approach is used to statistically downscale to 400-500 European stations (WP4 and WP5).

In order to provide a baseline for the future scenarios and, more specifically, to determine past changes in extremes, their impacts and potential causes, WP2 will focus on the analysis of observed data series from the second half of the 20$^{th}$ century. The GCM/RCM validation studies undertaken in WP3 will also focus on the ability of the models to simulate observed temperature and precipitation-based extremes in order to demonstrate the need (or not) for downscaling.

## 3.2 Project planning and timetable

**Introduction**

The STARDEX project will run for 42 months. Seven milestones can be identified over the project period (see below). The first of 20 project deliverables will be produced in Month 1, with the final deliverables due in Month 42 (see Table 4). A timetable showing the schedule for the WPs, milestones, deliverables, meetings and reporting is shown in Figure 1. The links between the WPs, including the flow of deliverables, are illustrated in Figure 2. The relationships between the WPs and deliverables are also shown in Table 5.

The STARDEX co-ordinator has experience of successfully co-ordinating large consortia in Frameworks 3 and 4 and is thus well-placed to manage the STARDEX consortium. The members' web site, email and ftp will provide essential electronic tools (together with progress reports and meetings) for project management, ensuring that all partners work efficiently and consistently towards the STARDEX objectives. The co-ordinator will be assisted by the WP leaders and the whole consortium will be guided by the expert advisory panel.

**Milestones**

The seven STARDEX milestones reflect the five measurable objectives of the project (see Section 2.1):

- ***Milestone 1 (M1)*** (1 month into the project): Start-up meeting – finalisation of the extremes to be studied and downscaled, regional case studies, potential predictor variables and data sources (Measurable Objective 1).

- ***Milestone 2 (M2)*** (4 months into the project): Standard data sets (station observations, Reanalyses, simulations from GCMs/RCMs and damages/impacts) for the regional case studies, together with a diagnostic tool for calculating a standard set of extreme event statistics, made available to all partners for use in WPs 2-5 (Measurable Objective 1).

- ***Milestone 3 (M3)*** (20 months into the project): Completion of work on the observational analysis of changes in extremes, their causes and impacts (WP2) – for input to WPs 3-5 (Measurable Objective 2).

- ***Milestone 4 (M4)*** (30 months into the project): Completion of work on the analysis of GCM/RCM output and their ability to simulate extremes and predictor variables (WP3) – for input to WPs 4 and 5 (Measurable Objective 3).

- ***Milestone 5 (M5)*** (30 months into the project): Production of recommendations on the more robust statistical, dynamical and/or statistical-dynamical downscaling methods for the construction of scenarios of extremes to be used in WP5 (Measurable Objective 4).

- ***Milestone 6 (M6)*** (41 months into the project): Completion of the production and assessment of scenarios of extremes for selected European regions (Measurable Objective 5).

- ***Milestone 7 (M7)*** (41 months into the project): Draft final report sent out to the partners and the expert advisory panel for review.

***Table 4: List of deliverables.***

**DL Deliverable list**

| Deliverable No | Deliverable title | Delivery date (Month) | Nature | Dissemination level |
|---|---|---|---|---|
| D1 | Members' web site | 1 | O | RE |
| D2 | Public web site | 1 | O | PU |
| D3 | Standard data sets of daily temperature and precipitation time series for selected European regions and for 400-500 locations across Europe | 3 | Da | RE |
| D4 | Standard data set of NCEP Reanalysis data | 3 | Da | PU |
| D5 | Standard data set of objective circulation patterns and indices | 3 | Da | PU |
| D6 | Standard data set of HadCM3, ECHAM4/OPYC3 and RCM output | 3 | Da | RE |
| D7 | Standard data set of damages (losses of life and economic) arising from specific extreme events | 3 | Da | RE |
| D8 | Diagnostic software tool for calculating a standard set of extreme event statistics | 4 | Me | PU |
| D9 | Summary of the analysis of observed extremes, their causes and damages | 10 | Re | PU |
| D10 | Recommendations on the best predictor variables for extreme events | 12 | Re | PU |
| D11 | Recommendations on variables and extremes for which downscaling is required | 14 | Re | PU |
| D12 | Downscaled extremes based on NCEP Reanalysis data (1958-2000) | 18 | Da | PU |
| D13 | Recommendations on the most reliable predictor variables and evaluation of inter-relationships | 24 | Re | PU |
| D14 | Downscaled extremes based on HadCM3 and ECHAM4/OPYC3 output (for the present day) | 30 | Da | PU |
| D15 | Improved statistical downscaling methodologies | 30 | Me | PU |
| D16 | Recommendations on the more robust statistical, dynamical and/or statistical-dynamical downscaling methods for the construction of scenarios of extremes | 30 | Re | PU |
| D17 | Downscaled scenarios based on HadCM3 and ECHAM4/OPYC3 output for the end of the 21$^{st}$ century for regions of Europe and 400-500 locations across Europe | 36 | Da | PU |
| D18 | Summary of changes in extremes, comparison with past changes and consideration of impacts/damages | 42 | Re | PU |
| D19 | Assessment of uncertainties associated with the scenarios | 42 | Re | PU |
| D20 | Final project report | 42 | Re | PU |

***Table 5: Schedule of workpackages and links between the workpackages and deliverables.***

| **WPL** | **Workpackage list** | | | | | |
|---|---|---|---|---|---|---|
| **Work-package No** | **Workpackage title** | **Lead Participant No** | **Person-months** | **Start month** | **End month** | **Deliv-erable No** |
| **WP1** | Data set development, co-ordination and dissemination | 1 | 42 | 0 | 42 | D1-D8 D20 |
| **WP2** | Observational analysis of changes in extremes, their causes and impacts | 11 | 80.5 | 0 | 20 | D9, D10 |
| **WP3** | Analysis of GCM/RCM output and their ability to simulate extremes and predictor variables | 9 | 99.5 | 0 | 30 | D11, D13 |
| **WP4** | Inter-comparison of improved downscaling methods with emphasis on extremes | 8 | 117 | 4 | 30 | D12, D14 D15, D16 |
| **WP5** | Application of the more robust downscaling techniques to provide scenarios of extremes for European regions for the end of the 21st century | 1 | 65 | 25 | 42 | D17, D18 D19 |
| | **TOTAL** | | **404** | | | |

**Figure 1: Schedule of work.**

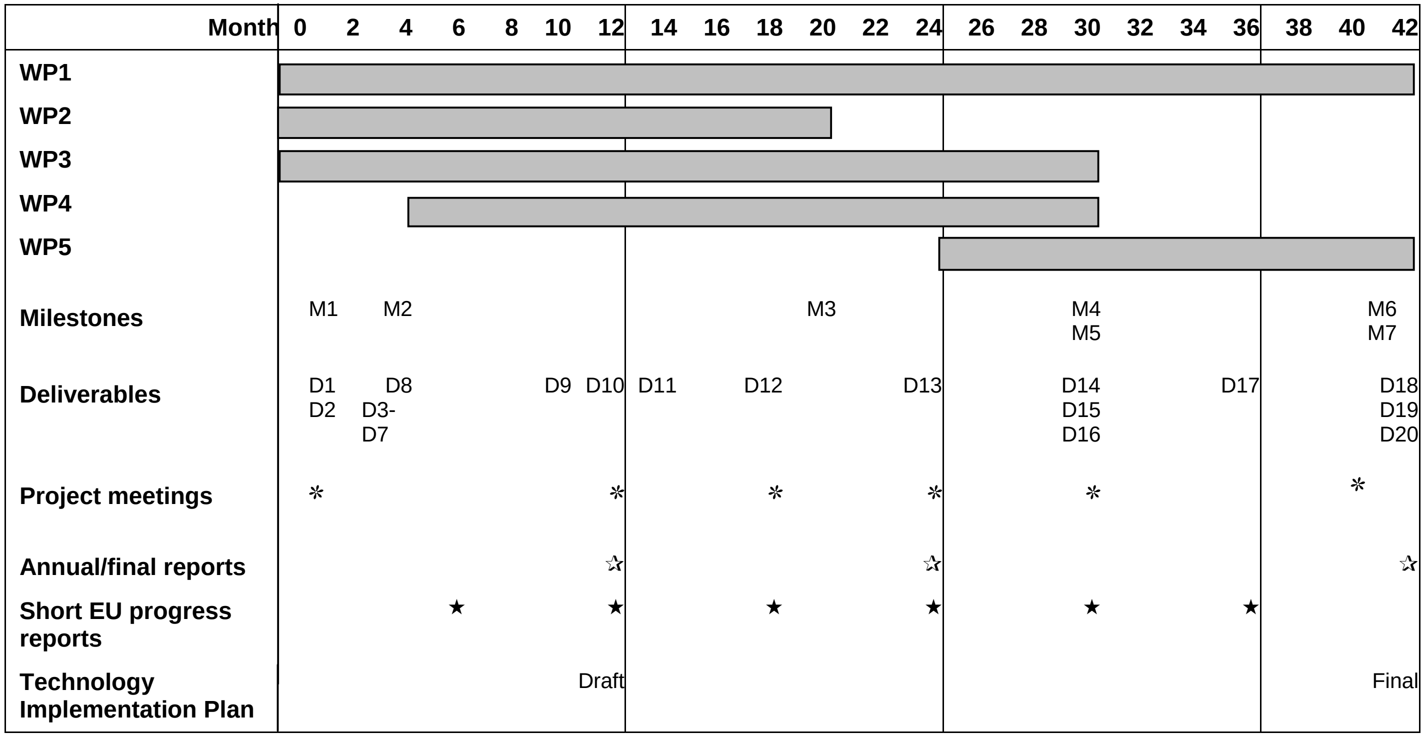
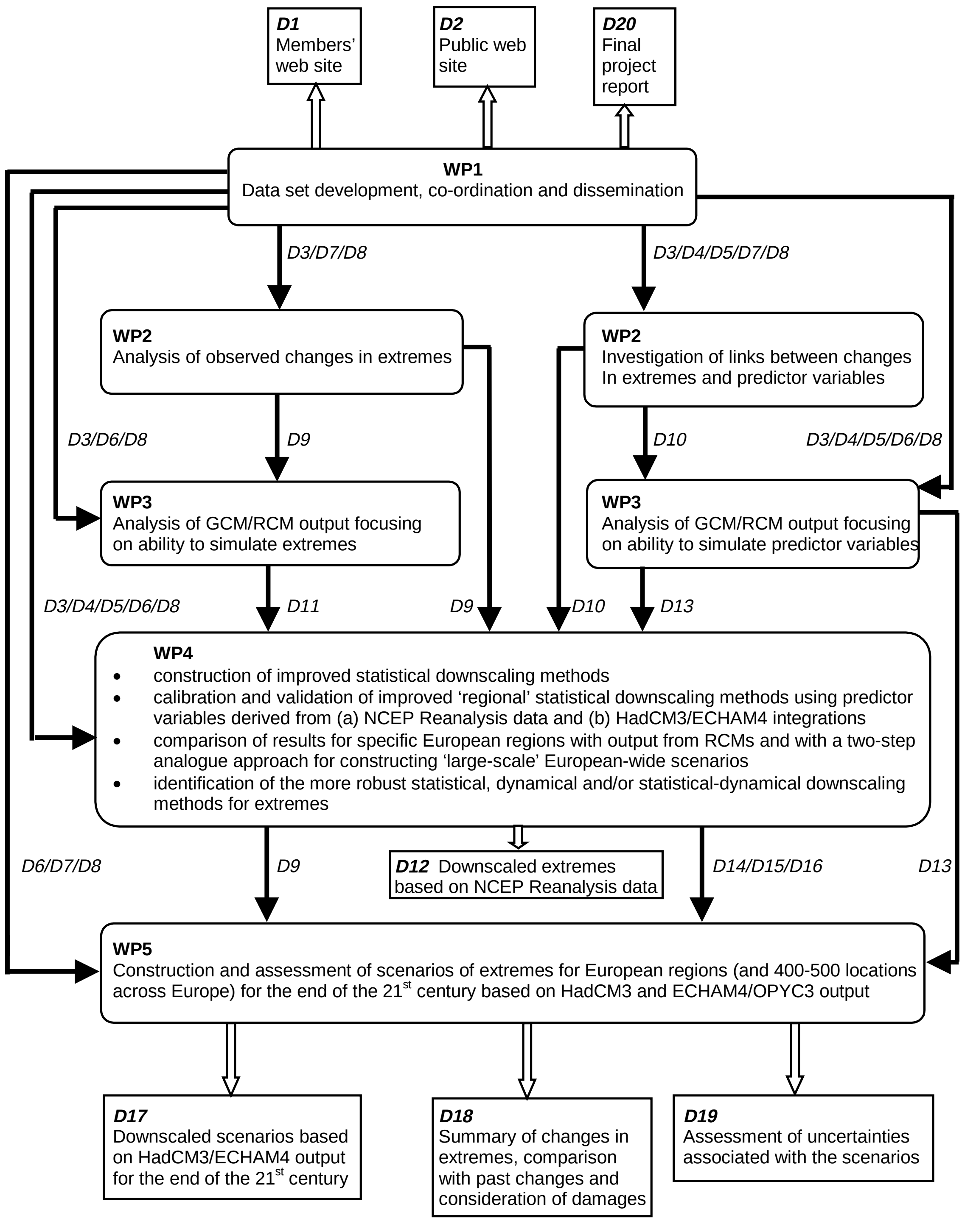


**Figure 2: Graphical presentation of the project's components.**



## 3.3 Critical path and risk of failure

The flow of information and data (i.e., the flow of deliverables) between WPs and the inter-linkages between WPs are shown in Figure 2. The scheduling of the work (Figure 1) is timed to reflect this flow, but with sufficient overlap in time to minimise any problems due to delays in any particular area of work.

The start-up meeting will focus on ensuring that appropriate data sets are available to all partners at an early stage in the project. Many of the required data (e.g., NCEP Reanalyses) are already available within the consortium, although some updating (for 1999 and 2000) will be required. While desirable to undertake analyses up to 2000, analyses can initially be undertaken up to 1998 only if problems arise with the updating. It is anticipated that the consortium will have access to the most recent GCM/RCM output (see WP3). However, if, for some unforeseen reason, it is no longer possible to have access to this output, the consortium will be able to use output from earlier simulations (for example, output from the HadCM2 and HadRM2 simulations is available through the Climate Impacts LINK project).

While some downscaling methods may be more successful than others and some, having been evaluated in WPs 2-4, may not be considered sufficiently promising for the production of scenarios in WP5, there are no major areas of work where there is a risk of complete failure. It may not, however, be possible to separate trends due to human and climatic influences in the damages data analysed in WP2. It is also possible that results from the intercomparison of the different downscaling methods may be ambiguous. Thus it may well be impossible, or undesirable, to identify a single 'best' method.

## 3.4 Detailed project description broken down into workpackages

### WP1: Data set development, co-ordination and dissemination (Table 8, WP leader: UEA)

Five major data sets will be used by the STARDEX consortium (see below). Catalogues and descriptions of these data sets will be made available on the members' web site, together with details of how to access them. Most of the data will be available by ftp, either directly from the members' web site or indirectly through other institutions/projects.

**(i) Station daily temperature and precipitation time series for selected European regions – to be provided by all partners**

Homogeneous station time series of daily temperature (Tmax, Tmin and Tday) and precipitation totals for the case-study regions will be collated from the data archives of the STARDEX partners, supplemented by additional data for Greece (from AUTH) and Scandinavia (from DNMI and SMHI). The series will extend back to 1958 (the start of the NCEP Reanalysis period) or earlier. In addition, a data set of daily Tmax, Tmin and precipitation totals for 400-500 major European stations will be obtained by FIC from NCAR.

**(ii) NCEP Reanalysis data – to be provided by UEA**

Gridded NCEP (National Centers for Environmental Prediction) Reanalysis data for an extended European window for the period 1958-2000 will be used to construct additional circulation indices and patterns [see (iii)] and as additional predictor variables for downscaling (see WP4). The major advantage of using the NCEP Reanalyses is that they extend further back than the European Centre for Medium-range Weather Forecasts European ReAnalyses (ECMWF ERA), which drive some RCM integrations used in WP3 but are only 15 years in length. [However, if ERA40 Reanalyses become available during the course of the project, NCEP and ERA40 data for selected case studies will be compared. ERA40 will be used in some of the downscaling methodologies if this proves possible and feasible.] NCEP Reanalysis variables such as sea-level pressure are considered reliable over the greater European area of interest (Reid *et al.*, 2001). NCEP does extend back to

1948 but the input radiosonde data have some serious problems with the pre-1958 temperature and humidity sensors (Elliott and Gaffen, 1991). The following variables will be available at 6-hourly intervals:

| **Surface** | **Pressure levels (1000, 850, 700, 500, 300, 200 hPa)** |
|---|---|
| Sea-level pressure | Air temperature |
| Precipitation rate | Geopotential height |
| Precipitable water | Relative humidity |
| Relative humidity | Specific humidity |
| Air temperature at 2m | |
| Specific humidity at 2m | |
| U-wind component at surface and 10m | |
| V-wind component at surface and 10m | |

**(iii) Objective circulation patterns and indices – to be provided by all partners**
The objective large-scale and regional circulation indices and patterns derived from NCEP Reanalysis data will include conventional indices such as the North Atlantic Oscillation, blocking and cyclone indices, together with indices/patterns derived using a range of different methodologies:

- generalised linear models;
- artificial neural nets;
- total shear vorticity and strength/direction of flow calculated from gridded sea-level pressure;
- fuzzy rules;
- spatial methods of topology and geometry; and,
- principal component analysis and cluster analysis.

Many of these indices and patterns have been developed by STARDEX partners during previous projects (principally, the EC-funded ACCORD project: http://www.cru.uea.ac.uk/cru/projects/accord/) and will be available at the start of the new project. Other indices will be developed and refined during STARDEX (WPs 2-4), focusing on optimised indices, i.e. robust, automated indices demonstrating strong relationships with extreme events.

**(iv) HadCM3, ECHAM4/OPYC3 and RCM output – to be provided *via* UEA, DMI and ETH**
A standard set of GCM/RCM output from state-of-the art models and, as far as possible, the most recent simulations including ensembles, will be made available through the members' web site. Output from the latest HadCM3 (obtained through the Climate Impacts LINK project) and ECHAM4/OPYC3 models will be used, together with output from RCMs driven by these two GCMs (see Section 3.1 and WP3 for details) and Reanalysis data. Output from statistical-dynamical RCM simulations will also be sought.

**(v) Damages arising from specific extreme events – to be provided *via* FTS and USTUTT-IWS**
The basis of this data set will be the Munich Re public data base 'World of Natural Hazards' available on CD. It is possible to search this data base for different natural hazards to create a table listing: country, date, hazard event, description of the region, fatalities and economic losses in million US$. Searches can also be made for particular countries, time periods and specific events (e.g. flooding, storms and heatwaves). Data from the non-public Munich Re archives can be made available to the consortium for a specific number of hazards in defined regions. The Munich Re data will be supplemented by additional data from other re-insurance companies with whom the consortium has links.

**Diagnostic tool – to be developed by KCL**
A diagnostic software tool for calculating a standard set of extreme event statistics (see Table 1), given inputs of daily temperature and precipitation time series, will be developed and made available to all partners (by downloading from the members' web site) for use in WPs 2-5. It will be made available from the public web site at a later stage in the project.

**Expert advisory panel**
The expert advisory panel will consist of representatives from the following areas:

- the re-insurance industry;
- hydrology/flood protection;
- Mediterranean impacts, e.g. heatwaves and forest fires;
- climate modellers, i.e. Hadley Centre, PRUDENCE; and,
- European climate impacts concerted actions and projects.

A number of people have been approached and have agreed to join the panel (see Section 9).

Members of the expert advisory panel will be invited to project meetings and will review the draft final report. On an ongoing basis, they will provide comment and feedback on the STARDEX work, suggest ways in which the work can best address the needs of users and stakeholders, and ensure widespread dissemination of the project results to appropriate organisations and individuals.

**The STARDEX web sites – to be constructed by UEA**
The project web sites will fulfil two important functions. First, the members' web site will provide central access and documentation relating to all the standard data sets to be used in the project. Second, the public web site will provide information about the project in a form suitable for stakeholders, the wider scientific community and the public. All public project deliverables will be available through this web site.

**Dissemination – all partners**
The project web sites (see above) will provide the quickest means for ensuring dissemination of the project results. As well as reports and scientific papers, a number of information sheets (available from the public web site) and brochures will be produced. Information sheets on the future scenarios, for example, will be produced for each case-study region, while others will cover methodological issues (e.g. the more robust downscaling methods). Members of the consortium will also be encouraged to present STARDEX work at major European scientific conferences.

**WP2: Observational analysis of changes in extremes, their causes and impacts (Table 9, WP leader: USTUTT-IWS)**
WP2 focuses on the analysis of observed data. This work will provide a baseline for the scenarios of extremes (WP5), identify the most appropriate predictor variables for the statistical downscaling of extremes (WP4) and provide appropriate validation data for statistical downscaling (WP4) and GCMs/RCMs (WP3).

Observed data series for the second half of the 20$^{th}$ century for the case-study regions (Table 3) will be analysed in order to identify any trends in the magnitude and frequency of occurrence of the standard set of temperature and precipitation extremes (Table 1, calculated using the diagnostic software tool from WP1) and, for selected case studies, derived indices and parameters (Tables 2 and 3). Each group will focus on the region in which they have particular expertise (Table 3).

For specific events (e.g. flooding, storms and heatwaves), the damages arising (in terms of losses of life and financial costs) will be identified from the Munich Re public data base 'World of Natural Hazards' available on CD, supplemented by additional data from other re-insurance companies with whom the consortium has links. The extracted information will be analysed for evidence of changes, using trend analysis where sufficiently long data series are available. Most of this aspect of WP2 work will be undertaken by FTS and USTUTT-IWS.

Relationships between the three extreme event data series (i.e. the standard indices, derived indices and damages) and a range of potential predictor variables will be explored by all groups involved in WP2. The predictor variables will be derived primarily from NCEP Reanalysis data and will include large-scale and regional objective circulation indices and patterns, such as the North Atlantic Oscillation, measures of atmospheric humidity and stability and sea surface temperature (see WP1 and WP4 for further details). Non-parametric methods will be used to identify critical large-scale variables which explain extreme events. The main aim of the investigations will be to determine whether changes in the extremes are related to changes in the predictor variables and to address questions such as "what kind of 'critical' circulation patterns are associated with observed extremes?". Changes in the occurrence, duration and strength of the large-scale features causing extremes will be investigated using a range of methods, including the trend and change detection methods suggested by the WCP (2000). The extent to which relationships between extremes and potential predictor variables may have changed in the past will also be explored, providing insight into the stationarity problem which will be explored further in WP4.

Techniques such as multiple regression, correlation and principal component analysis will be used in WP2, together with non-parametric methods, to explore and quantify relationships between the extremes and potential predictor variables. These relationships will also be tested using statistical downscaling methods in WP4. Thus there will be strong links and considerable feedback between WP2 and WP4, leading to the development of improved statistical downscaling methods in WP4.

Particular consideration will be given to the identification of the most appropriate and innovative statistical techniques for the analysis of extremes, focusing on the need to address problems such as statistical uncertainty and sample size. Logistic regression has, for example, been recommended for trend estimation and testing of discrete series of rare events (Frei and Schaer, 2001). It will also be possible to minimise some of these technical problems through the careful choice of extremes (Section 3.1). Particular care will be required in the analysis of the damages data set as the influence of changes in exposure to risk and other human influences needs to be considered (Changnon *et al.*, 2000). The problem of separating out trends due to climatic and human influences has been addressed during earlier projects in which UEA has been involved (Cannell *et al.*, 1999; see also the EU-funded WISE project: http://www.cru.uea.ac.uk/cru/projects/wise). This expertise will be beneficial for the STARDEX work.

The work carried out in WP2 will provide a strong observational basis for the statistical and dynamical modelling work to be carried out in WPs 3-5. It will, for example, provide an understanding of the physical processes which underlie the predictor/predictand relationships in the statistical downscaling models.

**WP3: Analysis of GCM/RCM output and their ability to simulate extremes and predictor variables (Table 10, WP leader: ETH)**

A rigorous evaluation, co-ordinated by ETH (the WP leader), will be carried out of GCM and RCM simulations of present-day climate as regards their ability to reproduce:

(a) the observed frequency and magnitude of extreme events (from WP2);
(b) the observed distribution and variability of circulation indices and other predictor variables used by the statistical downscaling methods (from WP4); and,
(c) the observed statistics and inter-relationships between extreme events and the predictor variables (from WP2 and WP4).

The purposes of the evaluation will be:

- to identify the need for, and value of, applying downscaling techniques for extremes (likely to be dependent on the region and the parameter considered);
- to assess the reliability of GCMs in simulating predictor variables (for present-day climate), and hence to point to the confidence of statistical downscaling techniques, developed with NCEP Reanalysis data, using these predictors;
- to quantify the skill of dynamical downscaling (for present-day climate), for comparison with the evaluations of statistical downscaling undertaken in WP4; and,
- to examine the degree to which dynamical downscaling reproduces the observed inter-relationships between large-scale circulation (and other predictors) and the occurrence of regional extremes (identified in WP2 and WP4), hence pointing to potential errors in the GCM/RCM model chain.

The standard set of temperature and precipitation extremes (Table 1, calculated using the diagnostic software tool from WP1) will be used for model evaluation in all case-study regions. In addition, derived indices (see Table 2) will be calculated from climate model output (where possible, depending on the availability and temporal resolution of the model data) for some of the case studies and compared to observations. Evaluation of the simulation of predictor variables and their inter-relationships with surface climate will involve the application of circulation classification/clustering algorithms to GCM output and the application of statistical downscaling techniques to output from the GCM/RCM model chains (Noguer 1994; Kidson and Thompson 1998, Murphy 1999).

**(i) Global models**
Simulations will be studied from the most recent versions of the HadCM3 (Gordon *et al.*, 2000; Pope *et al.*, 2000) and the ECHAM4/OPYC3 (Wild *et al.*, 1998; Roeckner *et al.* 1999; Stendel *et al.*, 2000) transient AOGCMs and new global high-resolution (T106, i.e. 150 km resolution) time-slice experiments with AGCMs of these models, all forced by the SRES emissions scenarios (Nakicenovic and Swart, 2000). The final decision on GCM selection will be taken at the project start-up meeting and in co-ordination with the modelling centres. This decision should ensure consistency with RCM modelling activities in other EU-projects (notably PRUDENCE), availability of multi-decadal model output (which is needed to ensure the statistical robustness of estimates of extremes), and the availability of downscaling predictors at a daily resolution. It is anticipated that output from the simulations listed in Table 6 will be available for use in the project.

In WP3, output from simulations **1** and **3** will be evaluated (see Table 6). This output will also be used to construct statistical downscaling models in WP4. In WP5, scenarios will be constructed using output from simulations **1**, **2** and **3** in order to investigate uncertainties due to inter-scenario (i.e., SRES A2 *vs* SRES B2), inter-model (i.e., HadCM3 *vs* ECHAM4/OPYC3) and intra-model (i.e., over the three HadCM3 SRES A2 ensemble members) variability.

**(ii) Regional climate models**
The evaluation of dynamical downscaling will include RCM simulations driven by:

(a) Reanalysis data sets (ECMWF Reanalysis, Gibson *et al.*, 1997); and,
(b) AGCM fields for a multi-decadal time window of 'present-day' climate.

Simulations for (a) have been carried out in the framework of a recently-completed EU project (MERCURE). They cover the period 1979-1993 and involve models with a spatial resolution of around 50 km (HadRM, HIRHAM, ARPEGE and CHRM). The evaluation of Reanalysis-driven RCMs will reveal model skill under conditions of (mostly) bias-free lateral boundary forcing (Machenhauer *et al.*, 1998; Noguer *et al.*, 1998), and will be *directly* comparable to similar evaluations of the statistical downscaling techniques using Reanalysis data (WP4). The evaluation will identify RCM biases, as well as the skill of these models in representing the observed interannual variations of extremes (Murphy, 1999).

Simulations of type (b) are planned in the framework of the PRUDENCE project and also as part of nationally-funded research projects. They will involve 30 year simulations with RCMs (including HadRM, HIRHAM and CHRM) at the 50 km resolution, using the same AGCM forcing as will be used for statistical downscaling (WP4). Also, a doubly-nested high-resolution RCM (CHRM: 14 km resolution, 5-year simulation) for the Alpine region and the Rhine river basin will be included. Output from statistical-dynamical RCM simulations (Fuentes and Heimann, 2000; Heimann and Sept, 2000) will also be sought, from the PRUDENCE consortium, for example. The evaluation of the GCM-driven RCMs will reveal the relative roles of GCM biases and downscaling errors in the reproduction of regional extremes.

**Table 6: GCM simulations for which output will be available.**

| Simulation | Model | Emissions scenario | No. of ensembles |
|---|---|---|---|
| *AOGCMs* | | | |
| **A** | HadCM3 | SRES A2 | 3 |
| **B** | HadCM3 | SRES B2 | 1 |
| **C** | ECHAM4/OPYC3 | SRES A2 | 1 |
| *High-resolution AGCM time-slice experiments (2071-2100)* | | | |
| **1** | HadCM3 | SRES A2 | 3 |
| **2** | HadCM3 | SRES B2 | 1 |
| **3** | ECHAM4/OPYC3 | SRES A2 | 1 |

**(iii) Observational reference data sets**

The STARDEX consortium has access to high-resolution climatological analyses and daily station records for the case-study regions extending over several decades (WP1). The different nature of model-grid point values (which represent grid-box averages) and station observations (true point values) will require appropriate up-scaling for each of the extreme variables and model resolutions (Mearns *et al.*, 1995; Osborn and Hulme, 1997). For the case-study regions with a focus on precipitation extremes (the Alps, Germany, Scandinavia and the British Isles), analyses from high-resolution non-GTS (global telecommunication system) networks (including many thousands of stations) will be used for the validation of RCM model simulations. The evaluation of circulation indices and other predictor variables for downscaling will be based on the NCEP Reanalyses.

**WP4: Inter-comparison of improved downscaling methods with emphasis on extremes (Table 11: WP leader: DMI)**

The statistical downscaling methods which will be evaluated by each partner are listed in Table 7.

***Table 7: Statistical downscaling methods to be tested by each partner.***

| Partner | Downscaling technique to be tested in WP4 | References |
|---|---|---|
| 1 UEA | • Conditional probabilistic weather generator<br>• Conditional analogue approach<br>• Multi-layer perceptron neural network<br>• Support vector neural network | Goodess and Palutikof, 1998<br>Goodess, 2000<br>Palutikof *et al.*, 2001<br>Trigo and Palutikof, 1999<br>Vapnik, 1998<br>Williams, 1998 |
| 2 KCL | • Hybrid weather generator/regression model<br>• Robust hydrological modelling | Wilby *et al.*, 1999<br>Wilby *et al.*, 2000 |
| 3 FIC | • Two-step analogue approach | Boren *et al.*, 2001<br>Ribalaygua *et al.*, 2001 |
| 4 UNIBE | • Neural networks<br>• Canonical correlation | Eckert *et al.*, 1996<br>Gyalistras *et al.*, 1994 |
| 5 CNRS | • Classification into clusters of large-scale circulation corresponding to intense or extreme events | Plaut *et al.*, 2001 |
| 6/7 ARPA-SMR ADGB | • Classification of large-scale circulation patterns corresponding to extreme weather regimes (strong precipitation events, high thermal anomalies) and multiple regression | Quadrelli *et al.*, 2001a<br>Quadrelli *et al.*, 2001b<br>Pavan *et al.*, 2000<br>Cacciamani *et al.*, 1994 |
| 8 DMI | • Probabilistic weather generator conditioned on vorticity and atmospheric humidity<br>• Regional climate modelling | Kaas *et al.*, 1996<br>Schmith, 2001<br>Christensen *et al.*, 2001 |
| 9 ETH | • Singular value decomposition<br>• Methods using moisture-related variables as a predictor<br>• Regional climate modelling | Bretherton *et al.*, 1992<br>Frei *et al.*, 1998<br>Heck *et al.*, 2000 |
| 10/11 FTS/USTUTT-IWS | • Fuzzy rules<br>• Links between frequencies of circulation patterns and regional flooding | Bardossy *et al.*, 1995<br>Caspary, 1996<br>Caspary, 2000 |
| 12 AUTH | • Multiple regression<br>• Canonical correlation<br>• Neural networks | Maheras *et al.*, 2001a<br>Maheras *et al.*, 2001b<br>Landman and Tennant, 2000<br>Trigo and Palutikof, 1999 |

The statistical downscaling methods will encompass methods for the construction of scenarios that are consistent between sites (multi-site scenarios) and between variables (multi-variate scenarios) on a daily basis. The methods will employ circulation indices and patterns as predictor variables. However, previous work has demonstrated that it is desirable to incorporate additional predictor variables because circulation changes may not be the only forcing factor, particularly for precipitation, and additional variables are needed in order to incorporate the effects of low-frequency variability (Wilby *et al.*, 1998; Wilby and Wigley, 2000). In order to address these aspects of the stationarity problem and to develop improved downscaling methods for extremes, a range of additional predictor variables will be investigated, such as:

- geostrophic wind at different geopotential heights;
- vorticity;
- thickness;
- humidity and stability-related parameters (such as low-level thermal advection);
- sea surface temperature; and,
- thermal, moisture and snow cover soil status.

The focus will be on those variables for which relationships with extreme events can be identified in the observations (WP2) and which are available from, and reasonably-well simulated by, climate models (WP3). These variables will then be incorporated in improved, statistical downscaling models.

The various improved statistical downscaling methods will be tested in as many of the case-study areas as possible, though it will not be appropriate nor feasible to apply all methods in all regions. Validation of the methods, focusing on the variables listed in Tables 1 and 2, will be carried out in two stages:

- First, using predictor variables derived from NCEP (1958-2000) Reanalysis data. This will allow the methods to be tested under near-perfect conditions and to determine whether they are able to reproduce past changes in the occurrence of extreme events (identified in WP2).
- Second, using output from HadCM3 and ECHAM4/OPYC3 integrations for a control period representing present-day climate. This will allow the effects of climate model biases (identified in WP3 and which may be different for the two underlying GCMs) to be evaluated.

Downscaled extremes for the case-study regions produced by the different statistical methods will be compared with output directly from RCMs and statistical-dynamical models (from WP3). Comparisons at the case-study level will also be made with downscaled extremes derived from a two-step analogue approach to 'large-scale' statistical downscaling (which will be applied to 400-500 station locations across Europe). It will also be possible to evaluate the downscaled extremes for the case-study regions derived by the different methods in the context of European-wide output from the RCMs and the large-scale downscaling method. This may assist, for example, in the identification of homogeneous European regions in which particular downscaling methods are likely to perform best.

The final task of WP4 will be to identify the more robust statistical, dynamical and/or statistical-dynamical downscaling methods. This subset of the techniques considered in WP4 will be used in WP5. This determination is likely to depend on the extreme and region being considered, on the basis of:

- present-day validation studies (this WP and WP2);
- inter-comparison of the scenarios obtained by different methods (this WP); and,
- analysis of the ability of the GCMs/RCMs to reproduce the statistics and inter-relationships of the observed predictor variables (see WP2 and WP3).

**WP5: Application of the more robust downscaling techniques to provide scenarios of extremes for European regions for the end of the 21$^{st}$ century (Table 12, WP leader: UEA)**

Using the more robust downscaling methods determined in WP4 (which are likely to be region and variable dependent), scenarios of extremes for European regions will be developed by all partners (except ADGB) for the end of the 21$^{st}$ century (2071-2100) using the latest integrations of HadCM3 and ECHAM4/OPYC3. This period, which is at the end of most GCM simulations, will be used in order to maximise expected changes in extremes (and because recent GCM/RCM simulations of future climate are restricted to this period).

The scenarios of extremes will incorporate three forms of uncertainty:

(i) uncertainty related to downscaling method(s);
(ii) uncertainty related to possible future emission paths; and,
(iii) uncertainty due to intra- and inter-model variability.

Uncertainty arising from (i) will be a direct input from WP4. Uncertainty arising from (ii) will be estimated using simulations forced by the SRES A2 and B2 marker scenarios which have cumulative $CO_2$ totals for 1990-2100 of 1862 GtC and 1164 GtC respectively. The A2 scenario is defined by the IPCC as a 'high' emissions scenario and B2 as a 'medium-low' scenario. Uncertainty arising from intra-model variability (iii) will be estimated using the three HadCM3 SRES A2 ensemble members (see WP3). Uncertainty due to inter-model variability will be explored by comparing statistical measures (using the diagnostic software tool) of scenarios based on HadCM3 and ECHAM4/OPYC3 output.

Scenarios of extremes (together with associated errors/uncertainties) will be constructed for the standard set of extreme indicators (Table 1) and the additional case-study indices (Table 2), to determine changes across the case-study regions and for Europe as a whole (standard indicators only). The project meetings and the input from the expert advisory panel (and others) will modify and expand upon these indicators to provide potentially more important measures of changes across Europe, e.g. measures more relevant to the insurance, water-industry and agricultural sectors.

The extent to which the changes indicated by the scenarios of extremes agree with the direction of observed changes in extremes (identified in WP2) will be investigated and the implications for the underlying causes of the observed changes explored. This investigation will focus on areas for which longer observed time series are available. If the changes are in the same direction, and the observed changes are reproduced by the downscaling models (WP4), is it possible to attribute the observed changes to anthropogenic effects? The extent to which it is possible to evaluate the potential impacts of the projected changes in extremes will also be considered, based on the damages in terms of losses of life and financial costs of the observed changes (WP2). This aspect of the work is, however, likely to be limited by the availability of appropriate data and the difficulties of extrapolating the scenarios to the tail end of the distributions. The influence of changes in exposure to risk and other human influences on observed damages also needs to be considered (Changnon *et al*., 2000; see WP2).

The scenarios of extremes will be available through the public web site and will be presented in detail in the final project report. Information sheets summarising the scenarios in non-technical terms (but still addressing methodological issues and uncertainties) will also be produced for each case-study region (see WP1).

***Table 8: Summary of WP1.***

## DWP Workpackage description

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Workpackage number : 1** | Data set development, co-ordination and dissemination | | | | | | | | | | |
| **Start date or starting event:** | **Month 0** | | | | | | | | | | |
| **Participant codes :** | **1 (Lead)** | **2** | **3** | **4** | **5** | **6** | **8** | **9** | **10** | **11** | **12** |
| **Person-months per participant:** | **10** | **6** | **4** | **3.5** | **1** | **3** | **2** | **4** | **1.5** | **2** | **5** |

**1 Objectives;**

- To ensure that a consistent approach (in terms of regions, observed and climate model data inputs, variables and statistics studied and time periods) is used for all analyses.
- To ensure that the needs of the climate impacts community for scenarios of extremes are taken into account, that output from the most recent climate model simulations is available for use in the project and that the work is subject to continuous assessment by the expert advisory panel.
- To ensure wide dissemination of the project results to stakeholders, the scientific community and the public.

**2 Methodology / work description;**

Catalogues and descriptions of the five STARDEX data sets (see deliverables – Table 4) will be collated and compiled and made available to the consortium through the members' web site.

The expert advisory panel will consist of representatives from the following areas: the re-insurance industry, hydrology/flood protection, Mediterranean impacts, climate modellers and European climate impacts. The panel will provide input and advice on an ongoing basis, and will also attend project meetings and review the draft final report.

The members' web site will provide central access and documentation relating to all the standard data sets compiled for the regional case studies. The public web site will provide information about the project in a form suitable for stakeholders, the wider scientific community and the public. All public project deliverables, together with reports and information sheets, will be available through this web site. Brochures outlining the work of the project will also be produced. Members of the consortium will be encouraged to produce scientific papers and to present STARDEX work at major European scientific conferences.

The members' web site, email and ftp will provide essential electronic tools (together with progress reports and meetings) for project management, ensuring that all partners work efficiently and consistently towards the STARDEX objectives. The co-ordinator will be assisted by the WP leaders and the whole consortium will be guided by the expert advisory panel.

**3 Deliverables;**

- Members' web site (D1).
- Public web site (D2).
- Standard data sets of (a) station daily temperature and precipitation time series for selected European regions and for 400-500 locations across Europe (D3), (b) NCEP Reanalysis data (D4), (c) objective circulation patterns and indices (D5), (d) HadCM3, ECHAM4/OPYC3 and RCM output (D6), and, (e) damages arising from specific extreme events (D7).
- Diagnostic software tool for calculating a standard set of extreme event statistics (D8).
- Final project report (D20).

**4 Milestones;**

- Start-up meeting – finalisation of the extremes to be studied and downscaled, regional case studies, potential predictor variables and data sources (M1).
- Standard data sets and diagnostic software tool for the regional case studies made available to all partners for use in WPs 2-5 (M2).
- Draft final report sent out to the partners and the expert advisory panel for review (M7).

***Table 9: Summary of WP2.***

# DWP Workpackage description

**Workpackage number : 2** — Observational analysis of changes in extremes, their causes and impacts

**Start date or starting event:** **Month 0**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Participant codes :** | **11 (Lead)** | **1** | **2** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **12** |
| **Person-months per participant:** | **15** | **4** | **6** | **8.5** | **4** | **10** | **4** | **8** | **4** | **9** | **8** |

**1 Objectives;**

- To analyse observed station and regional data series for the second half of the $20^{th}$ century from specific regions of Europe in order to identify trends in the magnitude and frequency of occurrence of extremes and, for specific events, their losses in life and financial costs.
- To investigate whether these changes are related to changes in potential predictor variables.

**2 Methodology / work description;**

Data sets to be used: D3, D4, D5, D7. Other inputs: D8.

Observed data series for the second half of the $20^{th}$ century for the case-study regions will be analysed in order to identify any trends in the magnitude and frequency of occurrence of a standard set of temperature (e.g. $10^{th}$/$90^{th}$ percentile values, diurnal temperature range and growing season length) and precipitation (e.g. magnitude and frequency of exceeding the $90^{th}$ percentile, simple daily intensity index and maximum length of wet/dry spell) extremes and, for selected case studies, derived indices and other series (e.g. thermal discomfort and fire hazard indices and runoff simulated by a robust hydrologic model).

For specific events (e.g. flooding, storms and heatwaves), the damages arising (in terms of losses of life and financial costs) will be identified from the Munich Re public data base 'World of Natural Hazards' available on CD, supplemented by additional data where possible. The extracted information will be analysed for evidence of changes, using trend analysis where sufficiently long data series are available. These changes may reflect changes in the occurrence of extremes and/or changes in exposure to risk, or other human influences.

Relationships between the three extreme event data series (i.e. the standard indices, derived indices and damages) and a range of potential predictor variables will be explored. The predictor variables will be derived primarily from NCEP Reanalysis data and will include large-scale and regional objective circulation indices and patterns, such as the North Atlantic Oscillation, measures of atmospheric humidity and stability and sea surface temperature. The main aim of the investigations will be to determine whether changes in the extremes are related to changes in the predictor variables (e.g. what kind of "critical" circulation patterns are associated with observed extremes?). Changes in the occurrence, duration and strength of the large-scale features causing extremes will be investigated using trend and change detection methods.

Techniques such as multiple regression, correlation and principal component analysis, together with non-parametric methods, will be used to explore and quantify relationships between the extremes and potential predictor variables. These relationships will also be tested using statistical downscaling methods in WP4. Thus there will be strong links and considerable feedback between WP2 and WP4.

Particular consideration will be given to the identification of the most appropriate and innovative statistical techniques for the analysis of extremes, focusing on the need to address problems such as statistical uncertainty and sample size.

**3 Deliverables;**

- Summary of the analysis of observed extremes, their causes and damages (D9).
- Recommendations on the best predictor variables for extreme events (D10).

**4 Milestones;**

- Completion of work on the observational analysis of changes in extremes, their causes and impacts – for input to WPs 3-5 (M3).

***Table 10: Summary of WP3.***

| | |
|---|---|
| **DWP** | **Workpackage description** |
| **Workpackage number : 3** | Analysis of GCM/RCM output and their ability to simulate extremes and predictor variables |
| **Start date or starting event:** | **Month 0** |

| **Participant codes :** | **9 (Lead)** | **1** | **3** | **4** | **5** | **6** | **7** | **8** | **11** | **12** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Person-months per participant:** | **16** | **12** | **11** | **10.5** | **7** | **15** | **8** | **8** | **2** | **10** |

**1 Objectives;**

- To analyse output from the HadCM3 and ECHAM4/OPYC3 GCMs (including separate members of ensembles), and RCMs driven both by these two GCMs and by Reanalysis data, focusing on their ability to simulate (a) extremes and (b) potential predictor variables.

**2 Methodology / work description;**

Data sets to be used: D3, D4, D5, D6. Other inputs: D8, D9, D10.

Multi-decadal GCM simulations of present-day climate conditions will be compared to appropriately up-scaled data sets of observed temperature and precipitation-related extremes in the case-study regions. Model errors in the distribution and variability of extremes will be quantified.

GCM-simulated circulation and moisture characteristics over the North Atlantic and European sector will be compared to the 40 year NCEP Reanalyses. The characteristics studied will include objective circulation indices (such as the North Atlantic Oscillation), the frequency and pattern of objective circulation clusters, atmospheric moisture transports, and other potential predictor variables for the statistical downscaling techniques (identified in WP2 and WP4). The reliability of the simulation of the various predictor variables will be quantified.

Temperature and precipitation-related extremes simulated by RCMs (at a 50 km resolution over the European domain) driven by observed boundary conditions (derived from ECMWF Reanalyses, 1979-1993) will be compared to observed extremes in the case-study regions (from WP2). For precipitation extremes, the comparison will be based on observational analyses from many thousands of stations, extending over the full period of the model simulations (ensuring statistical robustness of the comparison). The skill of the models in reproducing the mean occurrence and interannual variations of extremes will be quantified using measures consistent with those used for the evaluation of statistical downscaling methods in WP4.

The simulation of extremes by RCMs (at a 50 km resolution) driven by GCM output will be compared to observations (from WP2). The improvement compared to raw GCM output will be quantified to assess the value of, and need for, downscaling, which is likely to be dependent on the region and target variable considered. Results will be compared to Reanalysis-driven RCM simulations, and thus the role of GCM errors in the model chain will be assessed. The statistics and the inter-relationships between regional extremes and large-scale predictor variables will be examined, both in the GCM simulations and in the GCM/RCM model chain (including, if possible, statistical-dynamical RCM simulations). Deficiencies of dynamical downscaling in reproducing the observed inter-relationships will be identified.

The simulation of precipitation-related extremes in the Alpine region and for the Rhine river basin will be evaluated for a doubly-nested RCM at a resolution of 14 km. The benefits arising from the use of a high-resolution RCM for hydrological impact modelling will be assessed by comparison to results from coarser resolution RCMs.

**3 Deliverables;**

- Recommendations on variables and extremes for which downscaling is required (D11).
- Recommendations on the most reliable predictor variables and evaluation of inter-relationships (D13).

**4 Milestones;**

- Completion of work on the analysis of GCM/RCM output and their ability to simulate extremes and predictor variables – for input to WPs 4 and 5 (M4).

***Table 11: Summary of WP4.***

| **DWP** | **Workpackage description** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Workpackage number : 4** | Inter-comparison of improved downscaling methods with emphasis on extremes | | | | | | | | | | | |
| **Start date or starting event:** | **Month 4** | | | | | | | | | | | |
| **Participant codes :** | **8 (Lead)** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **9** | **10** | **11** | **12** |
| **Person-months per participant:** | **10** | **12** | **6** | **26** | **4.5** | **6** | **12** | **6** | **10** | **2.5** | **10** | **12** |

| | |
|---|---|
| **1** | **Objectives;**<br>• To improve existing circulation-based statistical downscaling methods so that they are able to reproduce observed extremes and to incorporate additional predictor variables in order to address the problem of stationarity.<br>• To calibrate and validate improved 'regional' statistical downscaling methods using predictor variables derived from (a) NCEP Reanalysis data and (b) HadCM3 and ECHAM4/OPYC3 integrations.<br>• To compare the results for specific European regions with output from RCMs and with a two-step analogue approach for constructing 'large-scale' European-wide scenarios.<br>• To identify the more robust statistical, dynamical and/or statistical-dynamical downscaling methods. |
| **2** | **Methodology / work description;**<br>Data sets to be used: D3, D4, D5, D6. Other inputs: D8, D9, D10, D11, D13.<br><br>The following statistical downscaling methods will be evaluated: probabilistic weather generators, canonical correlation, conditional analogue approach, two-step analogue approach, multiple regression, neural networks (including multi-layer perceptron networks and support vector neural networks), fuzzy rules, singular value decomposition and classification into clusters of large-scale circulation corresponding to intense or extreme events.<br><br>These methods will employ circulation indices and patterns as predictor variables, together with a range of additional predictor variables (such as humidity and stability-related parameters) in order to address the stationarity problem. The latter variables will be used to develop improved statistical downscaling methods which are able to reproduce observed extremes (from WP2).<br><br>Validation of the statistical downscaling methods, focusing on the extremes listed in Tables 1 and 2, will be carried out in two stages: first, using predictor variables derived from NCEP (1958-2000) Reanalysis data; and second, using output from HadCM3 and ECHAM4/OPYC3 integrations for the present day.<br><br>Downscaled extremes for the case-study regions produced by the different statistical methods will be compared with output from RCMs, statistical-dynamical downscaling models and with a two-step analogue approach for constructing 'large-scale' European-wide scenarios for a network of 400-500 stations.<br><br>The more robust statistical, dynamical and/or statistical-dynamical downscaling methods, which are likely to be region and variable dependent, will be determined on the basis of:<br><br>• present-day validation studies (this WP and WP2);<br>• inter-comparison of the scenarios obtained by different methods (this WP); and,<br>• analysis of the ability of the GCMs/RCMs to reproduce the statistics and inter-relationships of the observed predictor variables (see WP2 and WP3). |
| **3** | **Deliverables;**<br>• Downscaled extremes based on NCEP Reanalysis data (1958-2000) (D12).<br>• Downscaled extremes based on HadCM3 and ECHAM4/OPYC3 output (for the present day) (D14).<br>• Improved statistical downscaling methodologies (D15).<br>• Recommendations on the more robust statistical, dynamical and/or statistical-dynamical downscaling methods for the construction of scenarios of extremes (D16). |
| **4** | **Milestones;**<br>• Production of recommendations on the more robust statistical, dynamical and/or statistical-dynamical downscaling methods for the construction of scenarios of extremes to be used in WP5 (M5). |

***Table 12: Summary of WP5.***

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|---|---|---|---|---|---|---|---|---|---|---|---|
| **DWP** | **Workpackage description** | | | | | | | | | | |
| **Workpackage number: 5** | Application of the more robust downscaling techniques to provide scenarios of extremes for European regions for the end of the 21st century | | | | | | | | | | |
| **Start date or starting event:** | **Month 25** | | | | | | | | | | |
| **Participant codes :** | **1 (Lead)** | **2** | **3** | **4** | **5** | **6** | **8** | **9** | **10** | **11** | **12** |
| **Person-months per participant:** | **12** | **6** | **7** | **4** | **3** | **8** | **8** | **2** | **3** | **7** | **5** |

**1 Objectives;**

- To apply the more robust statistical, dynamical and/or statistical-dynamical downscaling methods to HadCM3 and ECHAM4/OPYC3 integrations for the end of the 21st century to provide scenarios of extreme events for European regions.
- To use these scenarios to identify changes in extremes.
- To investigate whether these changes are in accordance with recent observed changes.
- To consider their potential impacts in terms of losses of life and financial costs.
- To assess the uncertainties associated with the scenarios.

**2 Methodology / work description;**

Data sets to be used: D6, D7. Other inputs: D8, D9, D13, D14, D15, D16.

The more robust downscaling methods identified in WP4 will be used to develop scenarios of extremes for European regions for the end of the 21st century (2071-2100) using the latest integrations of HadCM3 and ECHAM4/OPYC3.

The scenarios of extremes will incorporate three forms of uncertainty:

(i) uncertainty related to downscaling method(s) (estimated in WP4);
(ii) uncertainty related to possible future emission paths; and,
(iii) uncertainty due to intra- and inter-model variability.

Uncertainty arising from (ii) and (iii) will be estimated using simulations forced by the SRES A2 and B2 marker scenarios and HadCM3 ensemble integrations, and by comparing scenarios based on HadCM3 and ECHAM4/OPYC3 output.

Scenarios of extremes will be constructed for the standard set of extreme indicators (Table 1) and the additional case-study indices (Table 2) in order to determine changes across the case-study regions and Europe as a whole (400-500 stations, standard indicators only). The scenarios will be available through the public web set and will be presented in detail in the final project report. Information sheets summarising the scenarios in non-technical terms will be produced for each case study (see WP1).

The extent to which the changes indicated by the scenarios of extremes agree with the direction of observed changes (WP2) will be investigated and the implications for the underlying causes of the observed changes (i.e. issues relating to attribution) will be explored. The extent to which it is possible to evaluate the potential impacts of the projected changes will also be investigated, based on the damages in terms of losses of life and financial costs of the observed changes (from WP2).

**3 Deliverables;**

- Downscaled scenarios based on HadCM3 and ECHAM4/OPYC3 output for the end of the 21st century for regions of Europe and 400-500 locations across Europe (D17).
- Summary of changes in extremes, comparison with past changes and consideration of impacts/damages (D18).
- Assessment of uncertainties associated with the scenarios (D19).

**4 Milestones;**

- Completion of the production and assessment of scenarios of extremes for selected European regions (M6).

## 4. Contribution to Objectives of Programme/Call

This proposal will contribute directly in a number of different ways to the EESD thematic priority 2.1.3 on 'Climate change prediction and scenarios, in support of the Climate Convention (UNFCCC)' which is part of EESD Key Action 2 on 'Global Change, Climate and Biodiversity'. STARDEX will provide new and more reliable high-resolution regional climate scenarios concerning anthropogenic influences on the magnitude and frequency of extreme events. The scenarios will be for daily temperature and precipitation-based extremes for the present day and the end of the $21^{st}$ century for a number of European case-study regions (in Spain, the British Isles, Scandinavia, Germany, Greece and the Alps) and for Europe as a whole (400-500 stations).

The work will lead to a better physical understanding and quantification of the links between observed extreme events and potential causal mechanisms over past decades. The proposed validation and inter-comparative studies will provide feedback and new insights to groups developing GCMs and RCMs and will, therefore, contribute to advances in climate modelling within the European Union and the wider international climate modelling community. The work will also address the changes in risk faced by particular economic sectors due to observed changes in the frequency and magnitude of extremes and provide future scenarios to assist in improved planning and development. A highly integrated approach will be taken to the problem of constructing high-resolution scenarios of extremes which will enable the uncertainties in the scenarios produced by the consortium to be quantified.

The need to make the expert knowledge and skills available within the project consortium to user groups and stakeholders, and to seek guidance and feedback from these groups, is fully recognised. Particular emphasis will, therefore, be given to the effective dissemination of the scenarios together with information about the advantages/limitations of their construction. User groups will be directly involved in the project as members of the panel of external advisors and as invited attendees at project meetings.

High-resolution scenarios of extremes are a vital scientific tool for investigating the potential environmental and socio-economic impacts of anthropogenic climate change. Such impact assessments are essential for the effective implementation, and future development, of European environmental and energy policy with respect to international treaties or conventions in the post-Kyoto world.

## 5. Community Added Value and Contribution to EU Policies

The EU has played a key role in mobilising international efforts to address the major environmental issue of global climate change due to increasing atmospheric concentrations of greenhouse gases arising from human activity. STARDEX will help to ensure that EU-funded climate research maintains its state-of-the-art position in a rapidly-evolving global arena. This in turn will maintain and enhance the scientific credibility of the EU, allowing it to continue its vanguard role in international debates and negotiations on global-change issues.

Domestic action on a country-by-country basis is essential to meet the Kyoto targets, but there is also a role for Community-based policies and measures. Domestic action and implementation of community-wide measures will only be effective if the business community and ordinary people are convinced of the need for action. Confidence in climate detection and attribution studies is growing in the scientific community, but such studies often appear remote and academic to many outside that community. There is a requirement for more personalised/localised information in order to persuade people of the need for climate-change mitigation, avoidance and coping strategies, particularly where these have economic implications, and to help identify appropriate strategies. It is through extreme events (such as floods, storms, droughts and heatwaves) – the focus of STARDEX - that many people most immediately experience the impacts of climate variability and change.

There has been a growing demand in recent years for more reliable, regional climate scenarios at high spatial and temporal resolutions which can be used in climate impact studies. This requirement is reflected in the EU concerted action initiatives ECLAT and ECLAT-2, for example. It has also been recognised by the IPCC, whose Third Assessment Report ('Climate Change 2001: The Scientific Basis'; http://www.ipcc.ch/), includes new chapters on downscaling and climate-scenario construction. More specifically, the work programme for the Fifth Framework Programme states the need for scenarios of changes regarding the scale and frequency of extreme events and impacts on natural resources, socio-economic systems and human health.

An understanding of the local climatic and socio-economic context is important for climate impact studies and for scenario construction. Each of the STARDEX groups has particular expertise and knowledge of different regions of Europe (and access to regional data sets) which will be beneficial for the case-study work. However, the work undertaken by each group will not be confined to a particular region. One of the key features of STARDEX, is that all participants will test their downscaling method(s) in a number of different regions and for a number of different extreme indicators. Participants will have access to standard observed, Reanalysis and climate model data sets for each case-study region and will look at a standard set of extreme indicators using a standard diagnostic tool. Thus *direct* inter-comparisons will be possible of the results produced by each group, allowing identification of the more robust downscaling methods. This subset of methods will then be used to produce scenarios of extremes for the late 21$^{st}$ century. These scenarios will be more reliable and plausible than those which could be produced by a single group working on its own.

Thus there are a number of major advantages in bringing the local knowledge of the STARDEX participants together in a European-wide consortium:

- it allows many different techniques and approaches to scenario construction to be *directly* inter-compared and evaluated;
- it permits the rigorous development and testing of methods in a wide-range of environments (from Mediterranean to Alpine to Scandinavian);
- it permits the development of transportable methods of scenario construction, facilitating the construction of scenarios for any region of Europe;

- it provides all groups with access to a larger and standardised pool of observed and model data;
- it provides a scientifically critical environment and expert feedback which should encourage the development of novel techniques and better solutions to the problems being addressed; and,
- it allows the involvement of user groups and stakeholders, such as the insurance industry, who have a European-wide rather than a parochial/national interest in the impacts of climate change.

There are particular advantages in the proposed work being undertaken by the STARDEX consortium. Many of the consortium members have experience of working closely together in the ACCORD project (http://www.cru.uea.ac.uk/cru/projects/accord/) which was funded as part of the EU Fourth Framework Programme. Over 20 scientific papers arising from ACCORD have been published in or submitted to major peer-reviewed journals. The main achievements of ACCORD were the development of robust and objective methods of classifying atmospheric circulation patterns and the quantification of circulation/surface climate relationships, all within the context of present-day climate variability. Statistical downscaling methods are based on the application of relationships identified in the real world between the large-scale and smaller-scale climate to model output. Thus the ACCORD work is of direct relevance to STARDEX.

As part of the ACCORD work, a number of quality-controlled data sets were produced. These include blocking and cyclone catalogues and a range of objectively-defined circulation indices from the hemispheric to the regional scale. Data sets of observed surface climate variables, such as long station time series of daily precipitation totals and maximum/minimum temperature, were also produced. All these data sets will be available for use by all STARDEX participants.

The STARDEX consortium is not restricted to observational climatologists, but has a strong mix of both modellers and observationalists. Thus it contains a wider range of expertise than is likely to be available at any one national level. It will contribute towards the parallel development of RCMs (dynamical downscaling) and the statistical approach to downscaling, providing the first extensive inter-comparison of the results of the two approaches for Europe.

The modelling expertise within the STARDEX consortium will be enhanced by the inclusion of partners (DMI and ETH) who are also involved in completed (MERCURE) and new (PRUDENCE) EU-funded projects on regional climate modelling. A representative from one of these projects will be invited to join the expert advisory group (see Section 9). The co-ordinator (UEA) is involved in the ECLAT-2 EU concerted action and it is intended that the STARDEX expert advisory group will include a representative from the ECLAT-2 steering group. The co-ordinator also hosts the IPCC-Data Distribution Centre and the Climate LINK Project (funded by the UK DETR for the dissemination of Hadley Centre model output). Involvement of partners in these other major projects and concerted actions will help to ensure that STARDEX has access to the latest, most appropriate model data and to ensure the widest possible dissemination of, and feedback on, the project results.

## 6. Contribution to Community Social Objectives

Climate scenarios underpin all climate impact assessment studies. The value of such studies is, therefore, limited by the availability of appropriate and reliable climate scenarios. Thus there is a growing demand for scenarios with higher and higher spatial and temporal resolutions for increasingly specialised applications within many different socio-economic sectors across the EU (including agriculture, water resources, energy, transport, tourism and public health), together with a need to reduce the uncertainties associated with the scenarios. It is these, somewhat conflicting, requirements which STARDEX aims to address, focusing on scenarios of extremes.

Climate impact studies are essential for the identification of those socio-economic activities and environmental areas which are most sensitive to climate change, and for the development of effective strategies for avoiding, mitigating and adapting to climate change. Thus climate impact studies and the scenarios on which they are based, have an indirect effect on the quality of life, employment prospects and the environment across Europe. They are essential tools for helping the EU to develop and implement its environmental policy, and to meet its international commitments and legal undertakings, including those arising from the Kyoto Protocol.

The particular focus of the STARDEX work is the investigation of extreme events. It is this aspect of climate change which tends to be of greatest concern to individuals. Extreme events impinge directly on people and businesses. Flooding, for example, is accompanied by economic loss due to the physical destruction of buildings, infrastructure and crops, by stress for the individuals affected and, at worst, by loss of life. During the ‘Odra’ floods which affected Central and Eastern Europe between 5 July and 10 August 1997, for example, 110 people died. Economic losses were estimated at 5,900 $10^6$ US$ and insured losses at 795 $10^6$ US$. More recently, 19 people died in northern Italy during the Piedmont-Valle d’Aosta flood (13-16 October 2000). The first estimate of the economic damages caused by this event is 500 $10^6$ Euro. Heatwaves impact negatively on human health, particularly for the elderly and most vulnerable. In 1987, for example, over 1500 people died in Greece as a consequence of a heatwave which persisted from 19-27 July and during which the maximum recorded temperature in Athens was 43.6° C. At the other end of the temperature scale, the occurrence of late or severe frosts may be damaging for agriculture, particularly for economically valuable crops such as fruit and vines. A vital question for individuals, businesses, planners and policy makers across Europe is whether such events will occur more frequently in the future, i.e. will the risks increase/decrease?

The contribution to community social objectives of the STARDEX work will be strongly dependent on the quality of the downscaling results. Thus, from the sound physical basis of the observational work, STARDEX aims to develop improved methods of statistical downscaling and to critically evaluate the performance of RCMs for dynamical downscaling. Only the more robust statistical, dynamical and statistical-dynamical downscaling methods will be used to construct scenarios for the late 21$^{st}$ century and the uncertainties associated with these scenarios will be quantified.

Ensuring the wide dissemination of the project results to stakeholders and the scientific community is one of the specific objectives of STARDEX. In part, this will be achieved through the expert advisory panel and through the production of scientific reports and papers. The public web site will also play a major role in the dissemination of results. As well as providing access to the reports and other scientific documents, the web site will provide access to a number of information sheets. Information sheets on the future scenarios, for example, will be produced for each case-study region. These will be written in non-technical language and thus will be of value to concerned members of the public as well as to the European impacts community. The plans of STARDEX participants for the dissemination and application of the project results within their own countries are outlined in Section 7.

STARDEX will also bring social benefits by building on previous work funded by the EU (the ACCORD project, see Section 5) and by further raising skill levels within the European scientific community. The STARDEX consortium will work together to ensure the efficient transfer and interchange of information, data and skills between all its members, ensuring that all benefit equally and maintain their state-of-the-art level of expertise. Each STARDEX group will be made up of a mixture of experienced researchers and younger post-doctoral researchers (many of whom will be new appointees). STARDEX will raise the level of expertise of the former individuals, and provide valuable training opportunities for the latter.

The European Commission has a strategy of mainstreaming equal opportunities in all EU policies. Particular account is taken in the Fifth Framework Programme of the need to promote the participation of women in the fields of research and technology development. The STARDEX consortium includes a number of women scientists, including the co-ordinator, of varying seniority. Opportunities to further increase the participation of women will be pursued wherever possible during the course of the project.

## 7. Economic Development and Scientific and Technological Prospects

STARDEX has 20 specific deliverables (D1-D20) which are listed in Table 4.

The first deliverable (D1) is the members' web site which will be set up by the co-ordinator. This will provide the main source of information and data for all participants. Wherever possible, the observed, Reanalysis and model data sets used in STARDEX (D3-D7) will be made available through the public web site (D2). Where the use of these data is restricted by third parties, they will only be available to participants through the members' web site. The diagnostic software tool for calculating a standard set of extreme event statistics (D8) will be publicly available.

The public web site will provide access to general information on the project in a form suitable for non-participants. Many of the Workpackage deliverables (D9-D11, D13, D16 and D18-D20) will be in the form of reports for public dissemination (including the final project report). These will be available from the public web site, together with progress reports prepared for project meetings and the annual reports prepared for the EU. Material from these reports, together with descriptions of the improved statistical downscaling methodologies (D15) will be incorporated into the user-friendly guidance and documentation prepared to accompany the climate scenarios for the present day and the end of the 21$^{st}$ century (D12, D14 and D17) and a series of information sheets written in a non-technical manner suitable for non-climatologists. All this material will be available on the public web site. In particular, it is hoped that the scenarios will provide valuable educational tools for school, college and university use.

The public web site will include links to individual partner web pages and to other relevant sites (such as the web sites of the EU-funded PRUDENCE and MICE projects). Efforts will be made to ensure that links back to the STARDEX web site are added to the web sites of relevant organisations, projects and individuals. This will help to publicise the work of the consortium and to develop contacts which may lead to further funding opportunities.

Thus the public web site will include material relevant for the climate impacts community, as well as more general/personalised information which is likely to be of greater interest to the general public. Members of the STARDEX expert advisory panel will be consulted over the design and content of the web site. All STARDEX participants will contribute to the promotion of the web site by seeking announcements/links through national climate change commissions and relevant interdisciplinary bodies at the interface of science/the public/politics.

A series of glossy brochures will also be produced outlining the work of the project. The first brochure, for example, will outline the objectives and the regional case studies. These brochures will be available through the public web site and will be distributed by partners at relevant meetings, conferences and open days.

In addition to the specific numbered deliverables, all partners will be encouraged to produce scientific papers for publication in the peer-reviewed literature and to present their STARDEX work at climate-related scientific conferences, such as the Assemblies of the European Geophysical Society, IGBP meetings (International Geosphere-Biosphere Programme), especially IGBP-BAHC meetings, International Meetings on Statistical Climatology, European Conferences on Applied Climatology, Reanalysis conferences, national and international conferences and meetings on Natural Hazards and Climate Change and on Water Resources Management and Climate Change and other relevant scientific meetings (such as ICANN, the annual conference of the European Neural Network Society) during the course of the three years of the project.

Ensuring dissemination of project results to relevant groups and maximising feedback from potential users is seen as a vital part of the STARDEX work. In part, this will be achieved through the expert advisory group and the involvement of partners (such as UEA, DMI and ETH) who have links with previous, ongoing and new projects on climate modelling and impacts (such as the UK Climate LINK Project, MERCURE, PRUDENCE and MICE). Involvement of STARDEX partners in EU concerted actions (such as ECLAT-2) will also be important in this respect. STARDEX should also be in a position to have an input to the preparations for the IPCC Fourth Assessment Report.

Involvement in STARDEX will allow all partners to develop and maintain a state-of-the-art position in scenario construction. The STARDEX work will identify the current best methods and the most promising for the future. It will also identify transportable methods for regional scenario construction. This means that it will be possible to construct scenarios for other regions and time periods, using output from different underlying GCMs and RCMs. Thus partners will be able to exploit other international and national sources of funding to carry out this work, further strengthening their economic position.

The STARDEX partners have specific strategic plans for using and exploiting the project results within their own countries, which will be described in detail in the Technology Implementation Plan (TIP). A draft TIP will be prepared at the end of the first year of the project and the final version submitted at the end of the project (Figure 1). A few examples of these specific plans are outlined below:

- The expertise gained at UEA will feed into research activities undertaken for the Tyndall Centre for Climate Change Research and the UK Climate Impacts Programme (UKCIP). The Tyndall Centre, based at UEA and launched in November 2000, is a national inter-disciplinary research centre dedicated to the identification, promotion and facilitation of sustainable solutions to the climate change problem. It is funded by the UK Research Councils, together with initial co-funding commitments from the Department of Trade and Industry and UEA.

- The STARDEX work will provide an important milestone for FIC in its strategic objective of operating a Climate Change Scenarios Dissemination Centre in Spain.

- STARDEX will allow UNIBE to gain experience in the application of neural networks and extreme statistics to climate research. The STARDEX results will feed into a web-based training course on sustainability including climate change, an initiative on virtual learning initiated by the Swiss climate research community. STARDEX will also foster links between the University of Bern and ProClim, the Swiss Forum for Climate Change, and the Swiss Center of Competence in Climate Research, both located at Bern and which will serve as additional dissemination channels for STARDEX.

- ARPA-SMR is extremely interested to define climate change scenarios in the territory of Northern Italy and especially in the sub-domain of the Emilia Romagna region. This type of information is essential and requested by decision makers in order to define actions, at local government level, to mitigate the impacts that a “new climate” may have on different activities. In particular, the main interest is the study of the feedbacks that a change in the statistical occurrence of extreme precipitation events has with the frequency of occurrence of flash floods and landslides.

- Through hosting the Danish Climate Centre, DMI is a focal point of Danish climate-related interests. Relevant information is disseminated to society through newsletters and “Climate Forum” meetings where scientists, decision makers, the press and others have an opportunity to meet. Thus the Centre will provide an excellent route for dissemination of the STARDEX work in Scandinavia. DMI also carries out national research in co-operation with, for example, hydrologists, where the impacts of climate change are studied. STARDEX will be highly relevant to this research.

- FTS and USTUTT-IWS have close links with the Water Resources Management Administration (WRMA) in Germany and the Building Insurance Company (BIC) of the State of Baden Württemberg (a state in which all buildings, by law until 1994, had to be insured against flood risk). Since the European insurance industry was opened up to competition in 1994 and following the highly destructive floods of 1993, 1995 and 1997 in southwest Germany, BIC has become very sensitive to, and interested in calculating, flood risks for different regions including non-stationary behaviour in the flood time series. STARDEX results, especially in downscaling extreme precipitation and floods, will be very important for decision makers in water resources management. The WRMA is also very interested in non-stationary behaviour and changes in precipitation intensity, peak flow, design floods (for example, the magnitude of the 100 year flood) and flood risk. For the upper German Danube, for example, a former 100-year flood calculated using peak flow data for 1926-1976 has been re-calculated as a 20-year flood using data for 1926-1999. STARDEX will allow FTS and USTUTT-IWS to provide German-based organisations such as BIC and WRMA with a fundamental scientific basis for handling such changes in climate-induced risks and hazards.

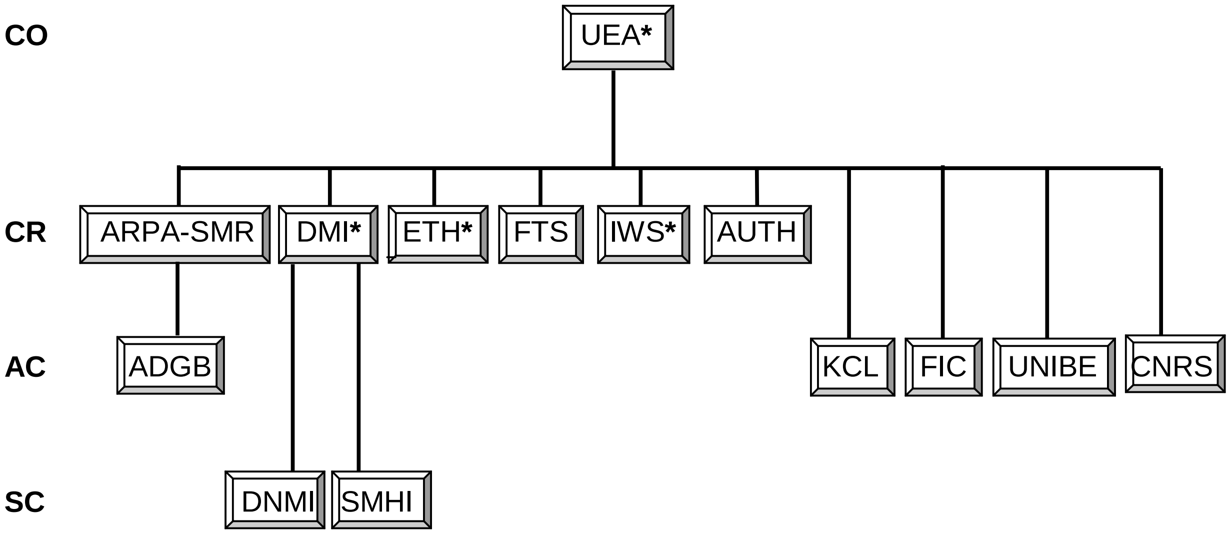
## 8. The Consortium

The STARDEX consortium consists of 12 partners (seven principal contractors and five associate contractors), together with two subcontractors. All these organisations are listed in Table 13. The key persons are also listed for each organisation. The final column lists the Workpackages (WPs) which each group will be involved with.

***Table 13: Summary of the consortium.***

| Partner number | Organisation name | Short name | Key persons involved | Involved in WPs |
|---|---|---|---|---|
| 1 | University of East Anglia, UK | UEA | Clare Goodess<br>Phil Jones<br>Steve Dorling<br>Gavin Cawley | 1, 2, 3, 4, 5 |
| 2 | King's College London, UK | KCL | Rob Wilby | 1, 2, 4, 5 |
| 3 | Fundación para la Investigación del Clima, Spain | FIC | Jaime Ribalaygua<br>Rafael Borén | 1, 3, 4, 5 |
| 4 | University of Bern, Switzerland | UNIBE | Evi Schuepbach | 1, 2, 3, 4, 5 |
| 5 | Centre National de la Recherche Scientifique, France | CNRS | Guy Plaut<br>Eric Simonnet | 1, 2, 3, 4, 5 |
| 6 | Servizio Meteorologico Regional, ARPA-Emilia Romagna, Italy | ARPA-SMR | Carlo Cacciamani<br>Valentina Pavan<br>Stefano Tibaldi | 1, 2, 3, 4, 5 |
| 7 | Atmospheric Dynamics Group, University of Bologna, Italy | ADGB | Ennio Tosi | 1, 2, 3, 4, 5 |
| 8 | Danish Meteorological Institute, Denmark | DMI | Torben Schmith | 1, 2, 3, 4, 5 |
| 9 | Eidgenössische Technische Hochschule, Switzerland | ETH | Christoph Frei<br>Christoph Schär | 1, 2, 3, 4, 5 |
| 10 | Fachhochschule Stuttgart – Hochschule für Technik, Germany | FTS | Hans Caspary | 1, 2, 4, 5 |
| 11 | Institut für Wasserbau, Germany | USTUTT-IWS | András Bárdossy | 1, 2, 3, 4, 5 |
| 12 | University of Thessaloniki, Greece | AUTH | Panagiotis Maheras<br>Theodore Karacostas<br>Margaritis Vafiadis<br>Fotini Kolyva | 1, 2, 3, 4, 5 |
| Subcontractor to Partner 8 | Norwegian Meteorological Institute, Norway | DNMI | Eirik Førland | 1 |
| Subcontractor to Partner 8 | Swedish Meteorological and Hydrological Institute | SMHI | Hans Alexandersson | 1 |

The relationships between the STARDEX groups are summarised below:




**CO** = Co-ordinator; **CR**= Principal contractor; **AC** = Assistant contractor;
**SC** = Subcontractor; ***** = Workpackage leader

The Workpackage leaders (UEA: WP1 and WP5; USTUTT-IWS: WP2; ETH: WP3; and, DMI: WP4) will make up the STARDEX scientific steering group (see Section 9).

The case-study regions will be selected from areas in which at least one of the partners has substantial expertise:

| | |
|---|---|
| Iberia: | UEA, FIC |
| British Isles: | UEA, KCL |
| Scandinavia: | DMI, DNMI, SMHI |
| Germany: | FTS, USTUTT-IWS |
| Alpine regions: | ARPA-SMR, ETH, UNIBE, ADGB, CNRS |
| Greece: | AUTH, FTS, USTUTT-IWS |

For the WP2 and WP3 analyses, the partners will focus on the areas listed above in which they have particular expertise. Some European-scale analyses will also be undertaken: for example, by USTUTT-IWS in WP2 and by ETH and FIC in WP3. The WP leaders (USTUTT-IWS and ETH) will be responsible for the inter-comparison and synthesis of results from the different regions.

For the WP4 analyses, partners will develop and test a range of downscaling methods in a number of different case-study regions and for a number of different extreme indicators. The principal techniques that will be used by each group are listed in Table 7

All partners will assist in the identification of the more robust downscaling techniques, although primary responsibility for this will rest with the WP4 leader (DMI) and the co-ordinator (UEA). In WP5, individual groups will be responsible for using this subset of methods to construct scenarios for the end of the 21st century for a number of different study regions. The local expertise of the partners (see above) will again be of value in the analysis of these scenarios, particularly with respect to potential impacts, while the co-ordinator and WP leader (UEA) will be responsible for the overall inter-comparison of the different scenarios.

**UEA (Partner 1)** will co-ordinate the project and will lead WP1 and WP5. The project co-ordinator will undertake a range of tasks related to project management (see above and Section 9) and will also work on the scientific tasks of the project. At the scientific level, UEA will focus on the use of conditional probabilistic weather generator and conditional analogue approaches to downscaling extremes for the Iberian Peninsula and the UK (and possibly other case-study areas), together with two innovative approaches involving neural networks. Multi-layer perceptron networks implement non-linear least-squares regression and support vector neural networks minimise the risk of overfitting. These four approaches will be developed and refined as part of WPs 2, 3 and 4 and, if successful, used to construct scenarios of extremes for the late 21$^{st}$ century in WP5.

| **Personnel** | 1 Senior Scientist | 3 Senior Researchers | 3 Permanent Academics | 2 Permanent technicians/other |
|---|---|---|---|---|
| **Expertise** | Project co-ordinator | Data extraction, manipulation and analysis | Scientific advice on data and methods. Interpretation of results. | Data support |
| **Contribution to WPs** | WP1-WP5 | WP1-WP5 | WP1-WP5 | WP1 |
| **Contribution to Milestones and Deliverables** | M1-M7<br><br>D1-D2, D9-D20 | M2, M4, M6<br><br>D1-D6, D9, D12, D14, D15, D17, D18 | M1, M3, M5, M7<br><br>D9-D11, D13, D15, D16, D18-D20 | M2<br><br>D3-D6 |

**KCL (Partner 2)** has worked extensively on the development and intercomparison of statistical downscaling models to study the implications of regional climate change for freshwater systems in Europe, North America and S.E. Asia. In STARDEX, the role of KCL will be to pursue this work through the development of diagnostic tools for extreme events in WP1, and their application to observed extreme weather events in WP2. In WP4, KCL will refine and validate existing statistical downscaling models, providing specific applications to extreme events downscaling in the UK and other case-study regions, and subsequent model intercomparison. In WP5, KCL will apply the downscaling model to future predictions of climate extremes.

| **Personnel** | 1 Junior Scientist | 1 Permanent-staff academic |
|---|---|---|
| **Expertise** | Software development, data extraction and model development | Principal investigator |
| **Contribution to WPs** | WP1, WP2, WP4, WP5 | WP1, WP2, WP4, WP5 |
| **Contribution to Milestones and Deliverables** | M2, M3, M6<br><br>D8, D9, D12, D14, D17, D18 | M1, M2, M3, M5<br><br>D8, D9, D10, D11, D15, D16, D20 |

**FIC (Partner 3)** has developed an advanced statistical downscaling procedure (a two step analogue approach) that has been shown to perform well, when driven with observed and GCM fields, in the generation of seasonal (average) fields of precipitation and temperature over the Spanish spatial domain. The method has been tested for the generation of simple climate statistics (mean values) and only for Spain. The robustness and physical basis of the method suggest that it can be used in other extratropical territories and for the generation of other climate statistics (e.g. extreme values). The main concern of FIC in STARDEX will be the assessment of the exportability of the method to the rest of the European territories, focusing on downscaling extreme values. In WP1, FIC will provide a daily dataset of temperature and precipitation for 400-500 European cities. In WP3, FIC's experience in analysing atmospheric fields (observed or GCM generated) will be useful for the detection of strengths and weakness of GCM and RCM simulations of extremes and potential predictor variables. In WP4, FIC will assess the performance of the method when driven with observed and current climate GCM generated fields. If this assessment is successful, FIC will apply the method to GCM integrations for the end of the 21$^{st}$ century, to provide scenarios of extreme events for 400-500 cities across Europe (WP5).

| | | | |
|---|---|---|---|
| **Personnel** | 1 Project funded Senior Scientist | 1 Project funded Researcher (junior scientist) | 1 Permanent-staff scientist |
| **Expertise** | To lead day-to-day work on the project | Data extraction and manipulation. Research duties | Principal investigator |
| **Contribution to WPs** | WP1, WP3, WP4, WP5 | WP1, WP3, WP4, WP5 | WP1, WP3, WP4, WP5 |
| **Contribution to Milestones and Deliverables** | M2, M4, M5, M6<br><br>D3, D4, D6, D11, D13, D12, D14, D15, D16, D17, D18, D19, D20 | M2, M4, M6<br><br>D3, D4, D6, D12, D13, D14, D15, D17, D18, D19 | M2, M4, M5, M6<br><br>D3, D4, D6, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20 |

**UNIBE (Partner 4)** has extensive experience in statistical data analysis, including extreme statistics, and downscaling methods to produce regional climate scenarios for the Alpine region. UNIBE also hosts the new Swiss Centre of Competence in Climate Change Studies. In STARDEX, the role of UNIBE will be to statistically analyse observations and model output with regard to changes in extremes over time (WP2 and WP3), and to explore the implications of regional scenarios for climate extremes in the Alpine region (WP 5). The relationships between objective circulation indices and circulation patterns over the Atlantic and European region, as established with the help of an artificial neural network, and extreme events will also be examined (WP2 and WP3).

| **Personnel** | 1 Senior scientist | 2 Junior scientists | 5 Permanent staff |
|---|---|---|---|
| **Expertise** | Lead day-to-day work on project | Statistical analysis of extremes, application of a neural network and implications of scenarios | Statistics (1), neural networks (2), computing (2) |
| **Contribution to WPs** | WP1-WP5 | WP2, WP3, WP5 | WP2, WP3 |
| **Contribution to Milestones and Deliverables** | M3, M4, M6<br><br>D8, D9, D10, D11, D12, D17, D18, D20 | M2, M3, M4<br><br>D8, D9, D10, D11, D12, D17, D18 | M2, M3, M4<br><br>D8, D9, D10, D11, D12 |

**CNRS (Partner 5)** has particular expertise in the study of extreme precipitation events in various Alpine sub-regions. CNRS is the joint-developer of a software package which allows automation of almost any numerical experiment using data. This package has been successfully used to develop a statistical downscaling method based on the classification into clusters of large-scale circulation corresponding to intense or extreme events. Using Alpine precipitation data as well as appropriate circulation indices linked to intense precipitation, CNRS will address the question of recent changes in extremes (WP2), and whether these changes are related to other predictor variables (such as SST anomalies). In WP3, CNRS will check the ability of GCMs to correctly simulate the large-scale circulation patterns (including their frequency) corresponding to intense and extreme events over various Alpine (or other) sub-regions, under present-day conditions. In WP4, CNRS will calibrate the downscaling methods using predictor variables (mainly large-scale circulation, but possibly others such as SST) derived from GCM integrations for the present day. The results will be compared with other approaches, including output from RCMs. In WP5, CNRS will produce scenarios for extreme events at the end of the 21st century, mainly for Alpine precipitation.

| **Personnel** | 2 Senior scientists | Post-doctoral student |
|---|---|---|
| **Expertise** | To lead the day-to-day work | To perform day-to-day analyses |
| **Contribution to WPs** | WP1-WP5 | WP3, WP4 |
| **Contribution to Milestones and Deliverables** | M2, M3, M4, M6<br><br>D1, D3, D10, D11, D12, D13, D14, D16, D17, D18, D20 | M6<br><br>D14, D17 |

**ARPA-SMR (Partner 6)** has worked in the past on topics concerning weather-type classification and local climate downscaling in the Alpine region of Italy. In STARDEX, the role of ARPA-SMR will initially be to investigate the statistics of extreme events in the Alpine region and the links of these events with large scale Atmospheric Circulation Patterns (ACPs) deduced from NCEP reanalyses and objectively defined Circulation Indices (WP1, WP2). The results of this study will allow the identification of the main ACPs which are linked with the occurrence of extreme events in the Alpine area and which can, therefore, be considered good predictors of these phenomena. The main practical objective of this study is to identify and propose a quantitative downscaling method.

After that, and within WP3, ARPA-SMR will focus attention on GCM/RCM model output. In detail, ARPA-SMR will study the ability of available RCM output to reproduce the extreme events observed in the Alpine region and also the quality of GCM output in reproducing the observed ACPs investigated in WP2. If the results of this last verification are good, the statistical downscaling procedures proposed in WP2 can be applied to GCM output and the downscaled extreme events compared with those directly simulated by RCMs (WP4). Finally, the downscaling method will be applied to GCM scenario runs (WP5) in order to simulate future extreme weather scenarios in the Alpine Region.

| | | | |
|---|---|---|---|
| **Personnel** | 1 Project-funded Senior Scientist | 1 Project-funded Junior scientist<br><br>1 Permanent technician | 1 Permanent-staff scientist |
| **Expertise** | To lead day-to-day work on the project | Data extraction and manipulation | Principal investigator |
| **Contribution to WPs** | WP1-WP5 | WP1 | WP2, WP3, WP4 and WP5 |
| **Contribution to Milestones and Deliverables** | M1, M2, M3, M4,M6<br><br>D5, D6, D8, D12, D14, D15, D17,D19 | M1, M2<br><br>D3, D5, D6 | M1, M3, M5<br><br>D9, D10,D11, D13, D16, D18, D19, D20 |

**ADGB (Partner 7)** has worked extensively on the climate of the Mediterranean region, developing theories and statistical studies on Alpine cyclogenesis and blocking. In STARDEX, the role of ADGB will be to apply its knowledge of these phenomena to develop a statistical downscaling method for precipitation (particularly extreme events) for the Alpine region. The techniques developed will be applied to the output from climate models to validate present-day climate simulations and to derive downscaled precipitation for scenario runs.

| **Personnel** | 1 Junior Scientist | 1 Permanent-staff scientist |
|---|---|---|
| **Expertise** | Data extraction and manipulation | Principal investigator |
| **Contribution to WPs** | WP2, WP3, WP4 | WP1, WP2, WP3, WP4, WP5 |
| **Contribution to Milestones and Deliverables** | M3, M4<br><br>D12, D13, D14 | M1, M3, M4, M5, M6, M7<br><br>D9, D11, D12, D13, D14, D17, D18, D20 |

**DMI (Partner 8)** has worked extensively with statistical downscaling techniques applied to the analysis of historical data and the construction of scenarios for future climate in the Scandinavian/Northern European region. In STARDEX, DMI will develop methods for statistical downscaling of daily precipitation and maximum/minimum temperature, from which scenarios of indices describing extreme precipitation and heat waves will be produced. The exact form of these indices will be decided during the project period.

The methods will build on results from a previous EU supported project, ACCORD, where the probability for a wet day and the mean precipitation amount on a wet day were conditioned using a daily local vorticity index. In STARDEX, new predictors, such as those describing humidity, will be tested. Furthermore, the methods will be applied to maximum/minimum temperature.

DMI will lead WP4.

The two subcontractors DNMI and SMHI will contribute to updating and extending an existing dataset of daily observations of temperature and precipitation. This will include selection of well-suited series, data extraction and quality-control.

| **Personnel** | 1 scientist | 1 permanent staff scientist | 2 permanent staff scientists (subcontractors) |
|---|---|---|---|
| **Expertise** | To perform day-to-day work | Principal investigator | Data extraction and quality control |
| **Contribution to WPs** | WP1-WP5 | WP1-WP5 | WP1 |
| **Contribution to milestones and deliverables** | M1-M7<br><br>D3, D5, D9, D10, D11, D12, D13, D14, D15, D16, D18, D19, D 20 | M1-M7<br><br>D3, D5, D9, D10, D11, D12, D13, D14, D15, D16, D18, D19, D 20 | M2<br><br>D3 |

**ETH (Partner 9)** has wide ranging research experience in climate data analysis and regional climate modelling. The variation of heavy precipitation events in the region of the European Alps is a special focus of these activities. The role of ETH in STARDEX is: In WP1: To derive objective analyses and standard statistics of precipitation extremes from a comprehensive dataset for the Alps (needed for calibration, evaluation and comparison of downscaling methods in WP3 and WP4). In WP2: To analyse long-term variations and trends in the occurrence of heavy precipitation in the Alps. In WP3: To evaluate the representation of statistics of extreme precipitation by GCM/RCM simulations for the European study regions (used for comparison with statistical methods in WP4). In WP4: To investigate the role of large-scale humidity predictor variables in a statistical downscaling model of extreme hydrological events. In WP5: To evaluate the possible change of heavy precipitation in the Alpine region and assess the degree of uncertainties. ETH will actively contribute to co-ordination with the PRUDENCE project and participate in the dissemination of the project results to user groups.

ETH will lead WP3.

| **Personnel** | 1 project-funded Senior Scientist | 1 Permanent-academic/scientist |
|---|---|---|
| **Expertise** | To lead day-to-day work on the project | Principal investigator |
| **Contribution to WPs** | WP1, WP2, WP3, WP4, WP5 | WP1, WP2, WP3, WP4 |
| **Contribution to Milestones and Deliverables** | M1, M2, M3, M4, M5, M6, M7<br><br>D2, D3, D6, D9, D10, D11, D12, D14, D15, D16, D19, D20 | M1, M2, M3, M4, M5, M7<br><br>D2, D3, D6, D9, D10, D11, D12, D14, D15, D16, D20 |

**FTS (Partner 10)** has worked extensively on the analysis of hydrological extremes with special emphasis on river flooding. In STARDEX, FTS will concentrate in WP2, together with USTUTT-IWS, on the identification of past extremes and their hydro-meteorological causes. Investigations will be made as to whether changes in the observed extremes are related to changes in predictor variables such as "critical" circulation patterns. In WP4, FTS will focus on the validation of an improved downscaling model for precipitation extremes, to be developed by USTUTT-IWS based on observed extreme precipitation and predictor variables derived from NCEP Reanalysis data. In WP5, FTS will downscale GCM-based scenarios for regions for which validation is undertaken in WP4, with special emphasis on changes in extremes in comparison to past extremes.

| **Personnel** | 1 Project funded Senior Scientist | 1 Project funded scientific assistant | 1 Permanent-staff scientist |
|---|---|---|---|
| **Expertise** | To lead day-to-day work on the project | Data extraction and manipulation | Principal investigator |
| **Contribution to WPs** | WP2, WP4, WP5 | WP1, WP2, WP4 | WP1, WP2, WP4, WP5 |
| **Contribution to Milestones and Deliverables** | M3, M5, M6<br>D9, D10, D12, D16, D18 | M1, M3, M5<br>D5, D7, D9, D10 | M1, M3, M5, M6<br>D5, D7, D9, D10, D12, D16, D18, D20 |

**USTUTT-IWS (Partner 11)** has worked extensively on the analysis of hydrological and hydroclimatological extremes. This work included both the analysis of local extremes and the links with large-scale meteorological features. In STARDEX, USTUTT-IWS will concentrate on the identification of past extremes and their causes in WP2. Based on this, the possibility of downscaling extreme precipitation (leading to flooding) will be studied in WP3. In WP5, climate change impacts of extremes in selected regions will be investigated.

USTUTT-IWS will lead WP2.

| **Personnel** | 1 Project-funded Scientist | 1 Project-funded Scientific assistant | 1 Permanent-staff scientist |
|---|---|---|---|
| **Expertise** | To lead day-to-day work on the project | Data collection and manipulation | Principal investigator |
| **Contribution to WPs** | WP1-WP5 | WP2 and WP4 | WP1-WP5 |
| **Contribution to Milestones and Deliverables** | M3, M4, M5, M6<br><br>D9, D10, D11, D12, D14, D15, D16, D18, D20 | M3, M5<br><br>D9, D12 | M3, M4, M5, M6<br><br>D9, D10, D11, D12, D14, D15, D16, D18, D20 |

**AUTH (Partner 12)** has a long tradition of work on topics related to climate change, climate variability and scenarios. In STARDEX, the role of AUTH will be to pursue this work, collecting daily time series data for Greece (WP1) and analyzing these data in order to identify trends in the magnitude and frequency of occurrence of extremes (WP2). AUTH will also use the output of GCMs/RCMs in order to evaluate their ability to simulate extremes and predictor variables for Greece (WP3). In Work Package 4, AUTH will evaluate the following statistical downscaling methods: canonical correlation, multiple regression and neural networks. Finally in WP5, AUTH will apply the more robust downscaling techniques to provide scenarios of extremes for Greece and other case-study regions for the end of the $21^{st}$ century.

| **Personnel** | 2 Senior Scientists | 2 Junior scientists | 5 Permanent-staff scientists |
|---|---|---|---|
| **Expertise** | To lead day-to-day work on the project | Data extraction, construction of software and manipulation | Principal investigators |
| **Contribution to WPs** | WP1, WP2, WP3, WP4, WP5 | WP1, WP2, WP3, WP4, WP5 | WP1, WP2, WP3, WP4, WP5 |
| **Contribution to Milestones and Deliverables** | M1, M2, M3, M4, M5<br><br>D3 – D6, D8-D20 | M1, M2, M3, M4, M5<br><br>D3 – D6, D8-D20 | M1, M2, M3, M4, M5<br><br>D3 – D6, D8-D20 |

## 9. Project Management

The project co-ordinator (UEA) will have overall responsibility for ensuring that STARDEX is managed effectively and efficiently, so that all project objectives (see Section 2.1) are met. UEA co-ordinated the ACCORD project which included many of the STARDEX partners. Thus they have good working relationships with the STARDEX consortium and will build on the project management expertise gained from ACCORD.

The co-ordinator will be assisted by a scientific steering group. This will be comprised of the five Workpackage (WP) leaders. The main role of this group will be to ensure the flow of expertise and data between WPs (Figure 2), and to ensure that the individual WP objectives (Tables 8-12) are met. The steering group will carry out most of its work via electronic means (email, ftp and web pages). It will, for example, produce an overall summary for the final technical report to be submitted to the EC. It will also produce a series of brochures outlining the work of the project. Regular project meetings are planned (Figure 1) and the steering group will convene during these meetings as necessary.

The co-ordinator will set up the two project web sites at the start of STARDEX. The members' web site will provide the main source of information and data for all participants. It will allow access to all the standard data sets required for the regional case studies and will include links to individual partner web pages. The public web site will provide access to general information on the project in a form suitable for non-participants, all the public deliverables (including the final scenarios) and, during the later stages of the project, a series of information sheets (see WP1). The web sites will continue to be updated for a reasonable period, at least a year, after the end of the project.

All STARDEX groups will be encouraged to work together on individual WP objectives and to maximise the free flow of information/data between WPs. Electronic means (email, web pages and ftp) will be used wherever possible. The co-ordinator will set up separate mailing lists for all participants, the steering group, and the expert advisory panel (see below) in order to facilitate email communication.

Six project meetings are planned: a start-up meeting, four progress meetings and a final meeting. The main component of each meeting will be thematic plenary sessions focusing on specific aspects of the work. The main aim of the start-up meeting, for example, will be to finalise the extremes to be studied and downscaled, regional case studies, potential predictor variables and data sources (Milestone 1). The final meeting will focus on the presentation of the final scenarios and dissemination of project results. A representative of the scientific staff in Brussels will be invited to this and some other meetings. The WP leaders will be responsible for co-ordinating the presentations to the plenary sessions at all meetings. The project meetings will also provide an opportunity for solving any problems which may arise concerning data availability and/or progress of work. Time for WP groups to meet on an individual basis will also be scheduled during each meeting.

The project meetings will provide the principal opportunity for input from the expert advisory panel. This panel is intended to ensure that potential users and stakeholders are actively involved in STARDEX and to contribute to quality assurance of the completed work. It is proposed that the panel should include the following representatives:

- the re-insurance industry (Dr Wolfgang Kron of Munich Re and Dr Gerhard Lemke of Swiss Re have agreed to be on the panel);
- hydrology/flood protection;
- Mediterranean impacts, focusing on heatwaves and forest fires (Prof. Pierre Carrega of the University of Nice – Sophia Antipolis has agreed to be a member of the panel);

- climate modellers from the Hadley Centre and/or ECHAM4/OPYC3 group, and from relevant EU projects (e.g. PRUDENCE); and,
- European climate impacts including a member of the ECLAT-2 steering group.

The role of the expert panel will be:

- to provide critical comment and feedback on the STARDEX work;
- to suggest ways in which the work can best address the needs of users and stakeholders;
- to ensure wide-spread dissemination of the project results to appropriate organisations and individuals; and,
- to review the draft final report.

Thus the scientific steering group, the expert advisory group and the project meetings all have vital roles in assuring the successful management and quality control of the STARDEX work. The co-ordinator will have a number of specific tasks and responsibilities to ensure that all three operate smoothly, including:

- setting up and up-dating the project web sites;
- maintaining data catalogues and archives for the project;
- setting up project mailing lists;
- liaison with the advisory group;
- organising project meetings (including circulation of agendas and minutes);
- submission of progress, annual and final reports to the EU;
- monitoring completion of milestones and deliverables; and,
- providing a final check on the quality of all deliverables before they are made publicly available.

All groups will have responsibility for checking the quality of data and software which they provide to the consortium. Much of the observed surface climate data (e.g. daily station data) to be used in STARDEX was obtained and subject to error checking as part of the EU-funded ACCORD project. ACCORD also completed assessments of the quality of much of the NCEP Reanalysis data which will be used in STARDEX. The possible availability of the longer ERA40 Reanalyses data during STARDEX will allow the two data sources to be compared and assessed. The quality of GCM and RCM output will be addressed in detail by STARDEX (see WP3).

All groups will be encouraged to publish in the peer-reviewed literature and to present their work at scientific conferences (see Section 7). This will provide additional opportunities for external assessment of the scientific quality of the STARDEX work.

The person months for project-specific temporary staff and permanent staff that will be spent on the project are shown in Table 14 for each partner.

**Table 14: The person months for project-specific temporary staff and permanent staff that will be spent on each workpackage.**

| **Project-specific staff:** | **Cost basis** | **WP1** | **WP2** | **WP3** | **WP4** | **WP5** | **Total** |
|---|---|---|---|---|---|---|---|
| UEA | AC | 6 | 3 | 11 | 11 | 9 | *40* |
| Co-ordinator | AC | 4 | 1 | 1 | 1 | 3 | *10* |
| KCL | AC | 6 | 6 | 0 | 6 | 6 | *24* |
| FIC | AC | 4 | 0 | 11 | 26 | 7 | *48* |
| UNIBE | AC | 3.5 | 8.5 | 10.5 | 4.5 | 4 | *31* |
| CNRS | FF | 1 | 4 | 7 | 6 | 3 | *21* |
| ARPA-SMR | AC | 3 | 10 | 15 | 12 | 8 | *48* |
| ADGB | AC | 0 | 4 | 8 | 6 | 0 | *18* |
| DMI | AC | 2 | 8 | 8 | 10 | 8 | *36* |
| ETH | AC | 4 | 4 | 16 | 10 | 2 | *36* |
| FTS | AC | 1.5 | 9 | 0 | 2.5 | 3 | *16* |
| USTUTT-IWS | AC | 2 | 15 | 2 | 10 | 7 | *36* |
| AUTH | AC | 5 | 8 | 10 | 12 | 5 | *40* |
| ***Total*** | | *42* | *80.5* | *99.5* | *117* | *65* | *404* |
| **Permanent staff:** | **Cost basis** | **WP1** | **WP2** | **WP3** | **WP4** | **WP5** | **Total** |
| UEA | AC | 2 | 1 | 3 | 3 | 4 | *13* |
| Co-ordinator | AC | - | - | - | - | - | - |
| KCL | AC | 1 | 1 | - | 1 | 1 | *4* |
| FIC | AC | 0.5 | - | 0.5 | 0.5 | 0.5 | *2* |
| UNIBE | AC | - | 4 | 2 | - | - | *6* |
| CNRS | FF | - | - | - | - | - | - |
| ARPA-SMR | AC | 1 | 5 | 6 | 5 | 3 | *20* |
| ADGB | AC | 1 | 4 | 7 | 7 | 1 | *20* |
| DMI | AC | 1 | 1 | 1 | 1 | 1 | *5* |
| ETH | AC | 2 | 1 | 2 | 1 | - | *6* |
| FTS | AC | 0.5 | 3 | - | 0.5 | 1 | *5* |
| USTUTT-IWS | AC | 0.5 | 3 | 0.5 | 2 | 1 | *7* |
| AUTH | AC | 6 | 7 | 10 | 10 | 5 | *38* |
| ***Total*** | | *15.5* | *30* | *32* | *31* | *17.5* | *126* |

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