Sustainable Urban Development Planner for Climate Change Adaptation (SUDPLAN)

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Abstract. SUDPLAN is an EU FP7 project combining IT and environmental knowhow in a novel way, bringing an easy-to-use, web-based decision support system for urban climate services. It will allow city planners to take climate change and its impact on the urban environment into account in the urban planning process. The main components of the SUDPLAN product are the Scenario Management System, the Common Services and the four pilot applications. This presentation describes the goals of the project, the consortium and the basic structure of the Scenario Management system and the Common Services. The usefulness of the system will be demonstrated in four pilot cities, but whatever European city can easily make use of the SUDPLAN Common Services offered.

Keywords: Scenario management, decision support, visualization, climate change, urban environment, SISE, SEIS

1 Introduction

SUDPLAN is an EU FP7 project under the Information Communication Technology programme (ICT-2009-6.4), running 2010-2012. The project responds to the call's target "ICT for a better adaptation to climate change" which asks for solutions that combine advanced environmental modelling and visualization, in support to EU initiatives like The 'Shared Environmental Information System' (SEIS) and The 'Single Information Space in Europe for the Environment' (SISE).

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1.1 Project goals

The main objective of SUDPLAN is to develop an easy-to-use, web-based, planning, prediction, decision support and training tool for urban climate services. The tool is to be based on a 'what-if' scenario execution environment. SUDPLAN visualization of future scenarios will allow city planners to take climate change into account in the urban planning process, thereby contributing to limit the effects of climate change on health, comfort, safety and quality of life.

SUDPLAN shall provide local information and a quality service to effectively support urban planners and decision makers in urban areas all over Europe in the areas of intense rainfall events, drought and flood risks, and severe air pollution episodes, affecting urban infrastructure and population under the influence of a changed climate. This goal will be achieved through:

- the design and implementation of a ***Scenario Management System***, an execution, visualization, documentation and training environment for scientific users, city planners and managers. This environment will seamlessly blend in existing and emerging distributed infrastructures for spatial data (SISE, SEIS)
- the design and implementation of so-called ***Common Services*** to deliver the necessary data to quantify, report and visualize the future risks for droughts, flooding, extreme rainfall intensities and high air pollution events over urban areas, usable throughout Europe, but at the local urban scale.
- validating SUDPLAN results in four independent pilot applications: the City of Stockholm in Sweden, the City of Wuppertal in Germany, the City of Linz in Austria and the Prague region in the Czech Republic.
- ensuring that the SUDPLAN services are generic enough to be easily applicable to other European sites.

1.2 SUDPLAN consortium

The different IT aspects of the SUDPLAN project will be covered by the four partners cismet (Germany), AIT (Austria), DFKI (Germany) and Apertum (Sweden). The environmental know-how will be taken care of by the two partners SMHI (Sweden) and TU Graz (Austria). Another three partners, representing environmental authorities and expertise, will ensure the validation and usefulness of the SUDPLAN tools: CENIA (Czech Republic), SULVF (Stockholm, Sweden) and Wuppertal municipality (Germany).

2 SUDPLAN main components

The main system components are shown in Fig. 1. The web-based Scenario Management System (SMS) includes the client and the user interface of SUDPLAN. The Common Services (CS) provides climate information and environmental modelling tools. The SUDPLAN infrastructure includes all city-specific models, sensors and databases. All SUDPLAN pilot cities have defined their own unique planning applications, managed together with Common Services through the Scenario Management System.

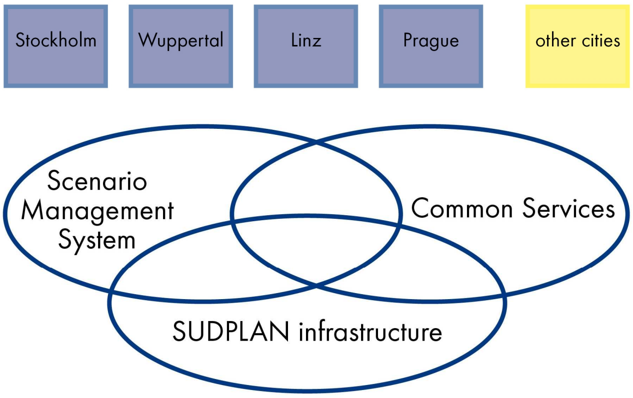

Fig. 1 Overview of SUDPLAN components

2.1 Scenario Management System

The Scenario Management System (SMS) will be a highly interactive, highly 3D/4D graphics-based decision support environment, which explores existing resources, in particular the 3D landscape and 3D models of phenomena. In this system, users are capable to define, manage, execute and explore different decisions and to simulate decision scenarios. Users are supported in the visualization, comparison and documentation of different decisions, and can use the system for training.

The SMS will contain the following major components (fig. 2):

a) a tentatively called “orchestrator” component, which allows to define different what-if decision scenarios, their data and sensor sources, the models involved and the work flow associated with the scenario
b) a tentatively called “executor” component, which allows to execute (i.e. compute) different decisions (while the user waits, or in the background), to compare and document results
c) a geo visualization component which links with existing SDI infrastructures (i.e. the existing spatial city information)
d) an advanced 3D / 4D visualization component for the visualization and animation of 3D results and predictions, in particular using the 3D landscape
e) a scenario and persistence manager which keeps an inventory of scenarios, data sources and results which supports results evaluation and reporting
f) an access-control layer to existing services (including models), data sources, catalogues and sensors.

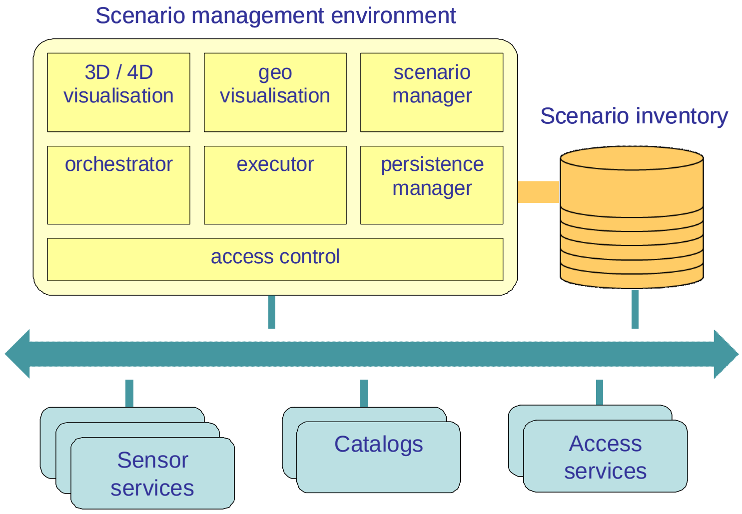

Fig. 2 Components inside the Scenario Management System

The functionality of the system includes (not including tools for system managers): discovery of resources available in the SUDPLAN scenario inventory (data, models, published scenarios etc.), integration support for data sources, sensors and models, support to set boundary conditions of models, scenario workflow management, scenario management repository support, post processing of results, advanced visualization capabilities. These functionalities will be available in a highly interactive adaptive "work bench".

2.2 Common Services

The Common Services (CS) task is to provide environmental information for European cities under present and future climate scenarios. A climate scenario means the resulting climate evolution over time, as simulated by a General Circulation Model (GCM), covering the globe and forced by a certain IPCC emission scenario. The spatial resolution is typically 200-300 km. Due to the uncertainties in climate modelling, SUDPLAN will provide various climate scenarios so that the planning can be based on an ensemble of different future scenarios.

A global climate scenario result may be downscaled to a higher spatial resolution, typically 25-50 km, by an Regional Climate Model (RCM). The regional downscaling in SUDPLAN will, at least initially, be performed by SMHI's RCM (named RCA) and will generate climate scenarios at 44 or 22 km resolution over Europe. As indicated in Fig. 3, the production of those European scale climate scenarios is an activity outside SUDPLAN.

Climate input →	CS database →	CS models →	Local models
Regionally downscaled climate scenarios over Europe	Precalculated European data of - intense rainfall - hydrological data - air quality	Urban downscaling of - intense rainfall - hydrological data - air quality	Pilot defined modelling
SMHI's RCA model (at least in first phase)	CS models over Europe executed by SMHI	CS models over cities executed by end-users	City-specific models executed by end-users
Input from GCMs (global models)	RCA model output used as input	Precalculated CS Europe results used as input	CS downscaling results used as input
External projects	*Common Services (CS)*		*SUDPLAN pilot applications*

Fig. 3 Overview of the SUDPLAN modelling of environmental factors, going from the European scale (left) to the urban and eventually finer scale (right). SUDPLAN involves the Common Services modelling as well as the specific modelling required by different pilot cities.

Regionally downscaled climate scenarios are today freely available through a number of project efforts, including EU FP6 ENSEMBLES project. For urban planning purposes, e.g. to give input to local models, the use of the climate scenario information freely available is coupled to some difficulties. The temporal and spatial resolution of the climate scenario information may not be adequate for the urban scale, as is often the case for short-term precipitation intensities that require 30 min or finer temporal resolution. Regional climate models also have a spatial scale that is too large for estimating intensive precipitation events. SUDPLAN Common Services will involve methods to bridge this scale gap of precipitation variability [1].

In order to transfer the regionally downscaled climate scenarios to other environmental factors of interest in urban planning, like river runoff, soil moisture and air quality, there is a need for complementary effect modelling. Common Services will bridge also this gap by offering model output from a hydrological model and a chemistry-transport model (CTM) forced by the climate scenarios for Europe. Again there is a need for higher spatial and temporal resolution. SUDPLAN will ensure that climate scenario information will be downscaled to become adequate for urban applications where intensive rainfall, river runoff and air quality are environmental factors of interest.

2.2.1 Climate scenarios

SUDPLAN will use available climate scenarios according to IPCC directed activities preparing for AR4[2] and currently for AR5[2] (through the CMIP5[3] coordinated model inter-comparison). The results of CMIP5 will be available in the

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[2] IPCCs Assessment Report no. 4, published in 2007 and no. 5, scheduled for 2014.

[3] Coupled Model Intercomparison Project Phase 5 (CMIP5) is a coordinated effort by the climate modeling community to validate their General Circulation Models (GCMs) and provide best possible estimates of future climate change to AR5.

end of 2010 or beginning of 2011, so for the first SUDPLAN version the AR4 scenarios will be used.
SUDPLAN will use regionally downscaled (over Europe) results from some well reputed global models. Initially the Common Services will be based on the following climate scenarios downscaled by SMHI's RCA3 model [2,3,4]:

- ECHAM5 [5] using A1B emission scenario [6]
- HADCM3 [7] using A1B emission scenario [6]

Later SUDPLAN versions will allow the use of other model results, both on the global and the regional (European) scale.

2.2.2 Downscaling of intense rainfall

Different methods will be used, depending on the type of input data selected by the end-user. The first alternative is input of an Intensity Duration Frequency (IDF) curve and the second a high temporal resolution time-series of precipitation.

The IDF curve downscaling is based on extreme value analysis of annual rainfall maxima of different durations using the Generalized Extreme Value (GEV) distribution, as outlined in e.g. [8]. For each selected scenario, this analysis is applied to one reference and one future, user-specified 30-year time-series of 30-min values from the five RCM model grid points surrounding the desired location. This means that the end-user inputs an historical IDF curve and will receive as output an IDF curve for a future climate scenario.

Time-series downscaling is based on the version of the general Delta Change (DC) method described in [1]. Essentially, short-term precipitation from climate scenarios are analyzed in order to estimate future changes associated with different intensity levels. As in the case of IDF downscaling, the analysis is applied to one reference and one future 30-year time-series of 30-min values. The end-user inputs the reference (historical) time-series and Common Services will give back a time-series representing the conditions of the selected future climate scenario.

Common Services will also offer a possibility to simulate the passage of a rainstorm over an urban catchment, generating multiple and consistent time-series in selected locations. The generator is based on the concept of a design storm, i.e. an idealized time-series of rainfall intensity during an intense event. In the generator, such a design storm is first defined for the centre of the rainstorm. Then transfer functions are used to create consistent design storms in selected surrounding locations. This transfer includes time lagging and a reduction of the peak intensity. The transfer functions should be designed to match the typical shape and extension of intense rainstorms, as found empirically (e.g. in [9]). For climate change impact assessments, the peak intensity will be changed to reflect the estimated future properties of intense rainfall. The Storm Generator simulation requires an IDF analysis as described above.

2.2.3 Hydrological downscaling

The concept used is to go from the CS database of pre-calculated hydrological data on the European scale, followed by an end-user executed downscaling where the local information is improved through re-calibration and re-running the CS hydrological model HYPE with improved local input. The local input can be river runoff data as well as improved land-use and watershed information.

The HYPE model [10] is a semi-distributed processed-based hydrological model for small-scale and large-scale assessments of water resources and water quality. In the model, the landscape is divided into classes according to soil type, land-use and altitude. The soil may be divided into up to three layers, each with individual computations of soil wetness and nutrient processes The model simulates water flows, and flow and turnover of nitrogen and phosphorus. Nutrients follow the same pathways as water in the model: surface runoff, macropore flow, tile drainage and groundwater outflow from the individual soil layers. Rivers and lakes are described separately with routines for turnover of nutrients in each environment. Model coefficients are global, or related to soil type or land-use. Internal model components are checked using corresponding observations from different sites. The model code is structured so that the model can easily be applied with high resolution over large model domains, which is also facilitated by linking coefficients to physical characteristics and the multi-basin calibration procedure.

The pan-European hydrological database in Common Services is generated by the water part of the HYPE model, applied in a multi-basin approach to Europe (E-HYPE). Model output cover most of the European continent, from the British Isles to the Ural Mountains, and from Norway to the Mediterranean Sea. This achievement was possible thanks to new global databases, which are handled in a specially designed system of methods for automatic generation of model input data [11]. The term multi-basin refers to a model calibrated homogenously over several entire river basins.. The pan-European model has at present a median sub basin resolution of 120 km^2, but incorporation of local observations can give a very good fit in both gauged and ungauged basins for national datasets with much higher resolution (median 18 km2 for Sweden [12]).

In the Common Services tool, the local user can select basins of interest from the pan-European model and may include further monitored time-series of water discharge. It will then be possible to run a simple automatic calibration routine for this domain to improve the multi-basin scale calibration. This will improve the model performance for present conditions. The user can then select climate scenarios using a relevant down-scaling technique (see above) to fit with the hydrological modelling on a very local level, also including storm-flow events. The user can then run the model in the new SUDPLAN interface, which uses the results to visualize the results of future risks of drought and floods in the selected basins. The monitored data inserted into the model by the local users will then be used in an annual re-calibration of the entire continent [12], which will improve the overall performance of the pan-European multi-basin model. Hence, more users will reveal more monitored data and the pan-European model will continuously improve in the long term

2.2.4 Air Quality downscaling

Also here the concept used is to go from the CS database of pre-calculated air quality data on the European scale, followed by an end-user executed downscaling where the local end-user executes the CS Chemical Transport Model over a specific city, with improved emission input (see Fig. 2).

The CS air quality model is named MATCH, an Eulerian off-line chemistry-transport model developed at SMHI. A comprehensive description of the model structure, boundary layer parameterization and advection scheme etc. is given in [13]. The photochemical scheme, based on [14] contains around 70 chemical species and around 130 chemical reactions. It is detailed in [15] which also includes an evaluation of the isoprene chemistry. MATCH's ability to realistically simulate air quality over Europe is discussed in a number of studies e.g. [16,17,18,19,20].

At least during the first phase of SUDPLAN, MATCH will be driven by climate scenarios from the Rossby Centre regional climate model RCA. A number of such applications have been published [21,22,23,24]

The first set of European air quality simulations will utilize one of the representative concentration pathways [25] to describe the evolution of tracer emission over the European continent during the present century. For the urban downscaling in pilot cities, locally provided emissions data will be used.

2.2.5 Communication services supporting Common Services

The communication layer between the clients (operating the Scenario Management System web interface) and the Common Services must be able to deal with both model execution as well as data transfer in both directions. SUDPLAN has the goal to use standardized OGC services, this to assure that new models – both in Common Services and in local city pilot applications - will be easy to connect to the core of SUDPLAN, the SMS system. The Sensor Planning Service (SPS) will be the first option for model execution in SUDPLAN. Access to the results requires a generic interface in order to enable clients (SMS) to access results in a unified way. For this purpose two standardized web service interfaces have been positively evaluated. Depending on the data type and organisation the Sensor Observation Service (SOS) and Web Coverage Service (WCS) shall be used. WCS, alternatively also Web Feature Service (WFS) and Web Map Service (WMS), will be used where results (grid, polygons, layers) shall be presented on a map.

3 Pilot specific applications

The usefulness of SUDPLAN tools will be demonstrated in four pilots. Stockholm will focus on air quality, where Common Services will allow the assessment of different city projections, under different climate scenarios. The other contribution will be the improved visualization possibilities of combined high resolution 3D and street canyon model output.

In Wuppertal storm water flooding is already a major problem, this due to the city's location in the steep, narrow and long valley of the Wupper river. SUDPLAN will help to assess both the damages that may be caused by flooding and the effectiveness of different planning options, thus providing decision support to the planners. Moreover the Scenario Management System will provide the means to visualize the results in advanced 2D-, 3D- and 4D-representations – as a basis for discussions with the concerned property owners.

The Linz pilot will develop planning tools for dimensioning of water sewer system, to mitigate future spill behaviour of combined sewer overflows (CSO). Also here storm water flooding is the problem, as hydraulic limitations of the waste water treatment plants will imply a discharge of polluted waters, either directly into the Danube river or to reservoirs for temporal storage. Through the use of a novel sensor network and model simulations, these combined sewer overflows and the sedimentation efficiency of the treatment plants will be assessed. Projections into the future will be possible through the Common Services precipitation scenarios.

The Czech pilot focuses the Prague region and how observed migration patterns correlate to environmental pressures. The hypothesis to be evaluated with the SUDPLAN tool is that a deteriorated air quality contributes significantly to an increased migration from the city to suburbs or adjacent areas. This is consequential because due to climate change an even more decreased environmental quality can be expected, with consequences on how the Prague population will live, commute and work in the future.

4 Conclusions

The SUDPLAN project is expected to generate results for the ICT and the environmental scientific communities, as well as for end-users represented by city planners.

The SUDPLAN communication and service infrastructure will be rely on standards and specifications of OGC. The web-based scenario management environment providing advanced modelling services to support the planning and decision making process has the ambition to be compliant with existing infrastructures supporting the emerging SISE (Single Information Space in Europe for the Environment). SUDPLAN Common Services will provide a number of climate scenarios from global climate models, downscaled first to the regional (Europe) scale and further downscaled to the urban scale. The downscaling will provide “best possible” estimates of future precipitation, temperature, hydrological and air quality.

The end-users of the SUDPLAN services are city planners who can either work directly in the system or they can benefit from SUDPLAN tools through different kinds of scientific users – IT, environmental modellers, statisticians etc. Through the use of SUDPLAN results end-users will be able to evaluate risk hazards of storm water local runoff, river flooding and elevated air pollution levels for planned or existing urban areas subject to a changing climate.

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