# How to Build Integrated Climate Change Enabled EDSS

Ralf Denzer [1], Sascha Schlobinski [2], Lars Gidhagen [3], and Thorsten Hell [2]

[1] Environmental Informatics Group (EIG)
`ralf.denzer@enviromatics.org`
[2] Cismet GmbH, Altenkesseler Strasse 17, 66115 Saarbrücken, Germany
`{sascha.schlobinski,thorsten.hell}@cismet.de`
[3] Swedish Meteorological and Hydrological Institute, Folkborgsvägen 1,
60176 Norrköping, Sweden
`lars.gidhagen@smhi.se`

**Abstract.** Results from global and regional climate scenario modelling predict significant changes in temperature and precipitation during the rest of the century. Episodes with extremely high temperatures and more intense rainfall will occur more often. Climate change will affect the urban environment and should be taken into account in long term and sustainable urban planning for adaptation to the new climate conditions. To consider the effects of climate change in today's planning, tools are needed to support the development of climate change enabled applications. These tools have to support several aspects of application development in the context of EDSS: a) How can the results from climate change models be integrated in today's applications? b) How to access climate change information? c) How to compare local effects of climate change scenarios? d) How to gain access to downscaling functionality required for local problems? e) How to feed local models with climate scenario data. Or in other words: How to build climate change enabled applications.

Within the FP7 project SUDPLAN, which integrates environmental modelling and software expertise, a system of standardised services and end user applications has been developed. The system delivers long term projections of environmental data for different aspects of local modelling (air quality, hydrological conditions and intense rainfall) based on different climate scenarios. The services are interactive and require input of local observations to improve downscaled projections. This is necessary to support wide applicability as the resolution requirements of local models can be very different. All services are provided through standardized service interfaces. On top of these services, the so-called Scenario Management System (SMS) provides end user components for scenario management, visualisation, model integration as well as wizards to support the relevant workflows and the interaction with common downscaling services. The SMS is based on the geo-spatial application suite CIDS which allows to build decision support systems (DSS) with a focus on using climate change projections in the workflow.

**Keywords:** Environmental Decision Support System, EDSS, 3D-visualisation, Climate Change.

# 1    Introduction

Climate Change (CC) is expected to have influence on the general environmental conditions of today and the future. As of today existing national action plans like the "Adaptation Action Plan of the German Strategy for Adaptation to Climate Change" [1]indicate that CC is recognized as an unavoidable reality. The potential impact of CC on society requires decision makers to consider direct or indirect effects of CC in many planning and decision making processes. Thus, CC is important to consider in EDSS that work on a larger temporal scale.

Available Climate change information from Global or Regional Climate Models (GCM's, RCM's) comes with a number of properties that need to be dealt with when using climate change projections in EDSS's.

In essence, climate change data consists of projections of meteorological variables like temperature and precipitation. To utilize this information in other environmental contexts the meteorological variables need to be mapped to environmental variables of the specific decision context (e.g. by a model). Climate change data is usually available on large scales. GCM's provide grids with a grid size of hundreds of km's, RCM's grids with a grid size of tens of km's. For many applications these grids need to be adapted to the higher resolution scale needed by local EDSS.

Another aspect is that climate change models produce climate change projections (climate scenarios) based on assumptions e.g. about future emissions. There is a number of established Climate Change Models available which produce different projections [1,2]. For each CC model different projections are available that might be relevant for the integration into an EDSS. In addition, CC models come with uncertainties that need to be somehow addressed if to be used in an EDSS.

How to utilize CC information for instance in the context of urban planning is subject to on-going research [3,4]. Issues to be dealt with include more than pure CC data related problems – particularly how to couple CC information with local experiments and how to visualise CC related phenomena.

This paper presents a discussion of which functionality is required in Climate Change enabled software. Concepts and possible realisations are based on the results of the FP7 project SUDPLAN [5], which integrates environmental modelling and software expertise, a system of standardised services and end user applications.

The SUDPLAN Scenario Management System (SMS) delivers long term projections of CC data (air quality, hydrological conditions and intense rainfall) based on different climate scenarios, which can in turn be used for different aspects of local modelling and decision support. The example of the SUDPLAN software is used to demonstrate how CC can be integrated in EDSS, from providing access to adequate climate change information, to the tools to link this information, and finally to the individual decision making problem.

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[1] http://www.bmu.de/fileadmin/bmu-import/files/pdfs/allgemein/
application/pdf/aktionsplan_anpassung_klimawandel_en_bf.pdf

## 2    Requirements for Climate Change Enabled EDSS

CC enabled software needs to provide access to appropriate climate change data. Appropriate in this context means CC information tailored to decision making process of the EDSS. The tailoring to be done includes:

- the temporal scale
- the spatial scale
- the environmental variables
- a sufficient number of climate change scenarios (as a means to deal with uncertainties of CC models)

Therefore EDSS using CC data need support to discover, explore, filter and select CC data to drive a specific local decision scenario. When dealing with CC a comparison of several relevant CC driven local scenarios is also needed, to estimate the potential impact of CC on the local problem. For this reason Scenario Management functionality, data comparison features and advanced simulation play an important role.

Another aspect is that CC enabled software needs to support the coupling of climate change data and the local decision problem. In the context of running a local simulation model to support the decision making process this means to transform CC data according to the requirements of a local model regarding formats, frequencies or anything that requires pre-processing of CC data before it can be used as input data (e.g. as boundary conditions) for a local simulation model. Moreover, flexible conversion, import and export mechanisms enable the analyst to use arbitrary tools to visualise, analyse, aggregate and correlate results of CC driven local scenarios.

## 3    Approach

Since 2010, the SUDPLAN project has designed and implemented a software framework for use of urban planners who need to assess the environmental impacts of storm water flooding, hydrological conditions and air quality in urban environments, under present and future conditions taking into account climate change scenarios. The primary target users for the SUDPLAN products are scientific users and city planners as well as environmental service providers [6]. The SUDPLAN solution provides two key elements of climate change aware urban planning:

1. Downscaled climate change projections of environmental variables based on ensembles of CC scenarios
2. Functionalities needed to consider and evaluate the effect of Climate Change in local planning processes, including climate data integration support facilities, model control, scenario management and advanced visualization capabilities.

SUDPLAN provides the means to downscale rainfall, hydrological and air quality data, taking climate change into consideration (Fig. 1). To obtain urban scale climate change data, end users provide local data which the downscaling services use to

generate downscaled versions of the CC data of the needed local resolution. This data can then be used as input for "CC-enabled" local models. This infuses the effect of climate change into the runs of local models. Planners can use their conventional local models to produce local model experiments (local scenarios) and climate change is considered through the CC-enabled input data and boundary conditions [7].

Different CC scenarios can be used as input to local planning scenarios, to compare the uncertainty of the climate change projections. Intervals of possible climate change effects can be identified and thus adaptation strategies can be considered in the planning process.
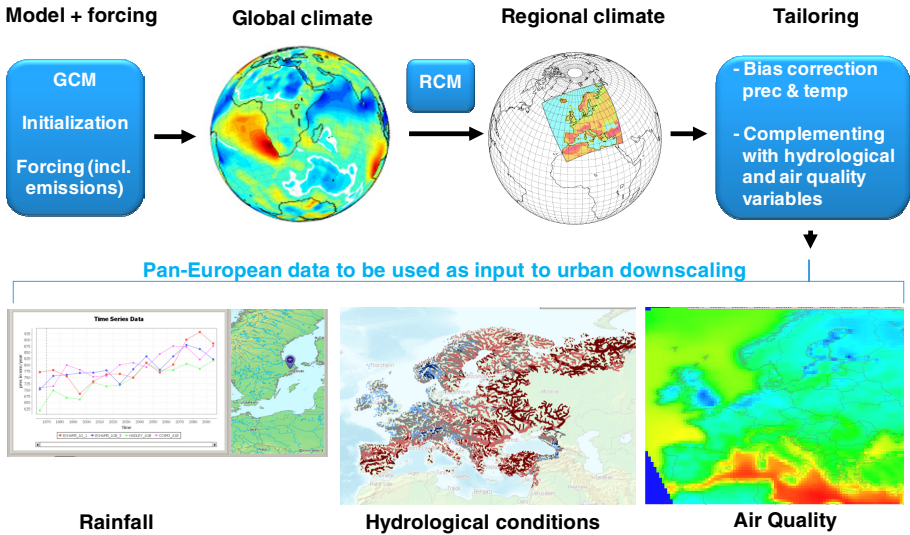
**Fig. 1.** CC data downscaling

The applicability of this approach to a large variety of decision processes is supported by using prominent open standard service interfaces. The transfer of time series or gridded data is through OGC Sensor Observation Services (SOS) and the model execution takes place through the OGC Sensor Planning Services (SPS) [8]. The use of these two standard interfaces also allows external users to access CC data in a well-defined manner and to incorporate CC data into applications.

## 4    Elements of CC Enabled EDSS

In the SUDPLAN framework the requirements discussed above are addressed by software components. Access to climate change data and downscaling functionality is provided through highly interactive GUI components. Wizards support the use of downscaling functionality and local model runs.

As a first step, end users gain access to CC data, including comparison and data analysis features for gridded and time series data from different CC scenarios (Fig. 2).
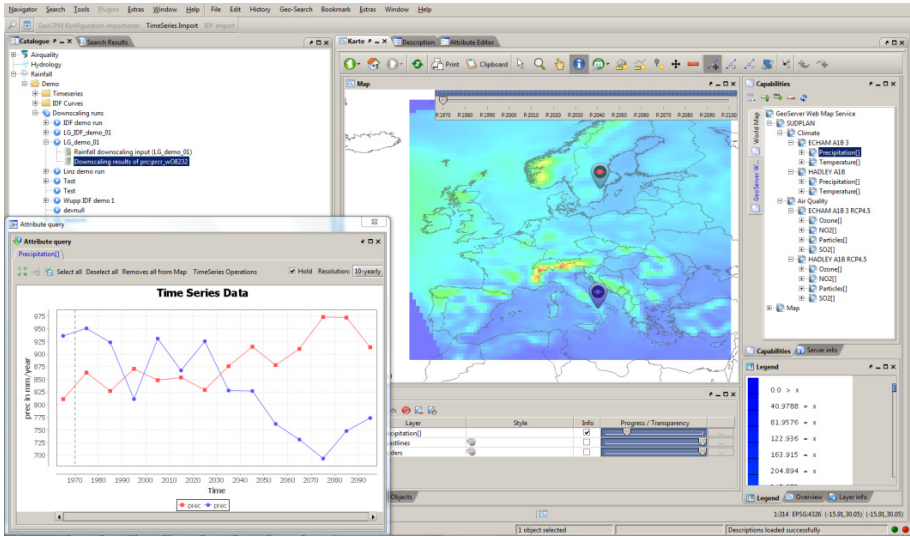
**Fig. 2.** Step 1: CC data access and visualization

In step 2, users can "upload" local data which serves to initiate the downscaling process. These processes are supported through wizards which guide users through the work flow.
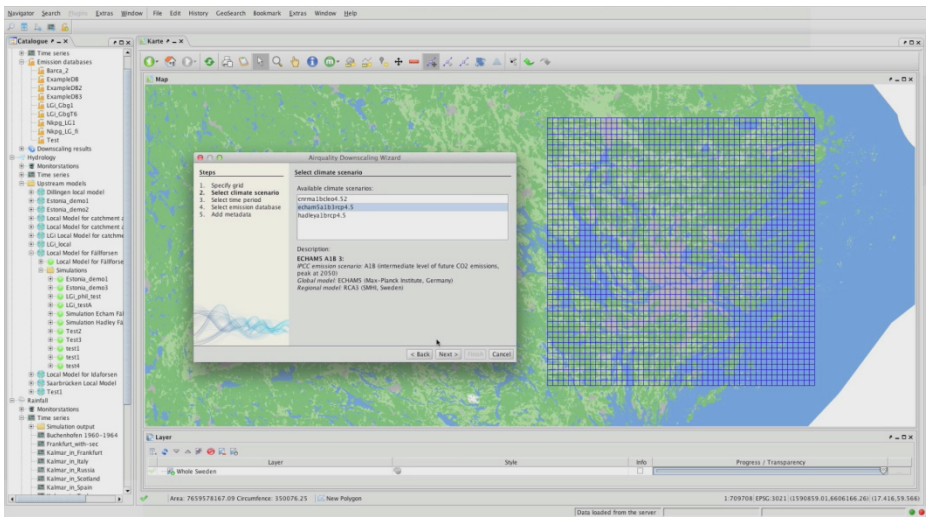


**Fig. 3.** Step 2: Downscaling wizard(example of air quality downscaling)

In step 3, users can couple the downscaled CC data to local models. This is where the actual "CC infusion" into the local decision process takes place, as the local models are run with the CC projections to produce local scenarios that are CC-enabled. This work flow is also supported through wizards.

In step 4, the exploration of multiple local scenarios, the management and visuali-sation of all related artefacts (model runs, model results,…) is handled by so-called model control components. These components enable users to run multiple variations and to compare results. Fig. 4 for instance shows the visualisation of results of a local sewer overflow model (SWMM, see [9]) which has been driven by downscaled rain-fall projections.
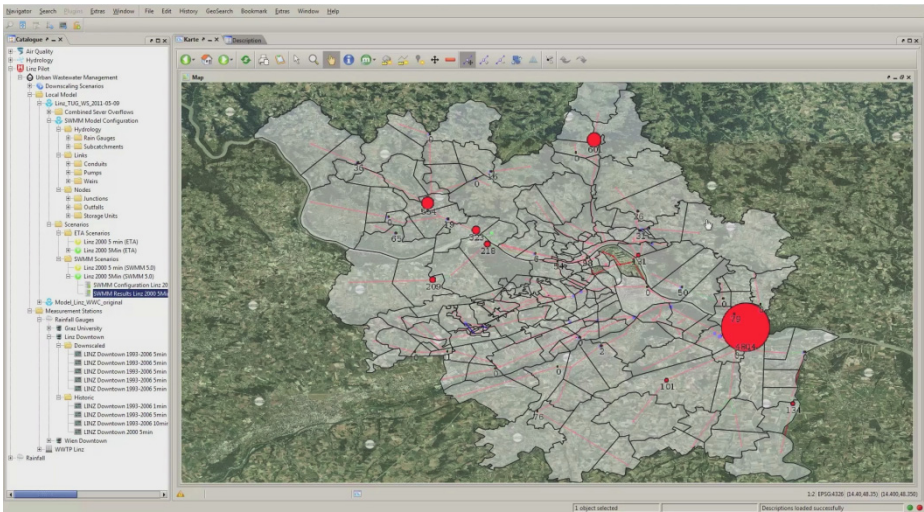


**Fig. 4.** Step 4: Comparison / visualization of local scenarios(example of a local sewer overflow scenario)
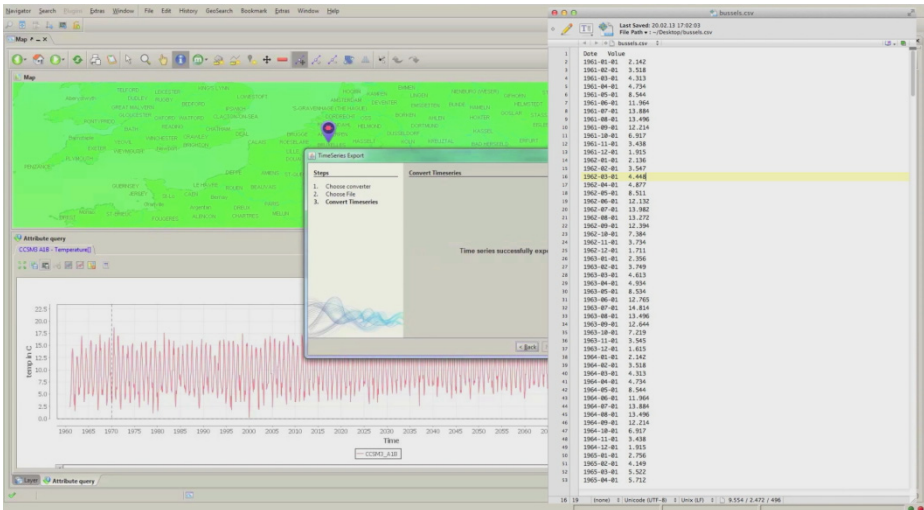


**Fig. 5.** Step 5: time series export

Finally in step 5, import, export and conversion functions supporting prominent formats in the respective domains, which enable users to utilize results in other tools like data analysis, statistics and specific post-processing tools. As an example **Fig. 5** shows the export of time series data to a csv file.

In order to produce material for decision makers that do not use an EDSS directly but rather are supported by an expert, the publication of results like the generation of maps and reports is part of the framework functionality.

# 5      Discussion and Conclusions

Dealing with CC data in EDSS means facing certain challenges. This paper identifies requirements and shows options for possible solutions as part of flexible framework to develop CC-enabled EDSS. The framework has been developed and validated in the context of the FP7 SUDPLAN project.

Currently, the development of CC-enabled software in general and EDSS in particular plays an insignificant role in integrated real world applications. However, this might change over time when the effects of climate change become more important for local planning.

**Software Baseline.** The SUDPLAN solution has been implemented with a stack of freely available open source software. The core of the solution is the ***CIDS product suite*** of CISMET GmbH. This product consists of a set of software components, application programming interfaces (APIs), management and development tools, services and applications, with a special focus on interactive solutions which need to integrate geo-spatial systems with databases, sensor networks, document-oriented systems, unstructured information sources and numerical models. CIDS uses freely available open source software exclusively, is itself freely available as open source software, distributed as github [2] projects, and is compliant with all major OGC services. The framework is freely available as an open source software project under http://sudplan.cismet.de/download.html.

# References

1. Roeckner, E., Arpe, K., Bengtsson, L., Christoph, M., Claussen, M., Dümenil, L., Esch, M., Giorgetta, M., Schlese, U., Schulzweida, U.: The atmospheric general circulation model ECHAM4: model description and simulation of present-day climate. Report No. 218. Max-Planck-Institut für Meteorologie, Hamburg (1996)

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[2]  `https://github.com/cismet`

2. Gordon, C., Cooper, C., Senior, C.A., Banks, H., Gregory, J.M., Johns, T.C., Mitchell, J.F.B., Wood, R.A.: The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. Climate Dynamics 16, 147–168 (2000)
3. Schlobinski, S., Denzer, R., Frysinger, S., Güttler, R., Hell, T.: Vision and requirements of scenario-driven environmental decision support systems supporting automation for end users. In: Hřebíček, J., Schimak, G., Denzer, R. (eds.) ISESS 2011. IFIP AICT, vol. 359, pp. 51–63. Springer, Heidelberg (2011)
4. http://www.grabs-eu.org/
5. http://www.sudplan.eu/
6. SUDPLAN Final Report, http://sudplan.eu/polopoly_fs/1.30418!SUDPLAN_final.pdf
7. Schlobinski, S., Gidhagen, L., Olsson, J., Frysinger, S., Denzer, R., Kutschera, P.: Integration of Climate Change Effects in Local Models and Urban Planning Processes, In: International Congress on Environmental Modelling and Software, pp. 826–834 (2012),
http://www.iemss.org/society/index.php/iemss-2012-proceedings
8. http://www.opengeospatial.org
9. Camhy, D., Gamerith, V., Steffelbauer, D., Muschalla, D., Gruber, G.: Scientific Data Management with Open Source Tools – An Urban Drainage Example. In: Proceedings IWA/IAHR 9th International Conference on Urban Drainage Modelling, Belgrade (2012)