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1 Management summary

SUDPLAN provides planning, decision support and training tools that help decision makers and planners to evaluate how different environmental conditions and problems on the urban scale will evolve under a changing climate. Common Services offer web based urban downscaling services for intense rainfall, river flooding and air quality; accessible through the Scenario Management System. The downscaling simulation results are improved by local data from the end user, i.e. Common Services can be described as interactive climate services.

Common Services represents, as the name suggests, a common functionality to be used by all four SUDPLAN pilot cities. In fact, what is here described can be applied in all European cities. The following specific Common Services are implemented within SUDPLAN:

- Climate scenario information on the European scale – visualisation of simulated future climate, hydrological and air quality conditions over Europe region with access to time series of daily averages of climate, hydrological and air quality variables from user selected locations.

- Intense rainfall: urban downscaling – generation of short-term precipitation data (continuous and event-based) for urban hydrological climate change impact assessment
  &
  Intense rainfall: design storm generator – generation of data for design and performance assessment of urban hydrological systems, including climate change

- Hydrological conditions: downscaling of upstream catchment area – local calibration of the hydrological model and generation of future runoff scenarios

- Air quality: urban downscaling – generation of local future air quality scenarios taking into account local emissions

SUDPLAN pilots will focus on different Common Services:

- Stockholm: Air quality

- Wuppertal: Intense rainfall (producing surface flooding)

- Linz: Intense rainfall (producing sewer overflows)

- Prague: Air quality and hydrological conditions

The end-user requirements regarding the pilot applications have been investigated in depth during the WP2 task 2.1 Knowledge compilation and T2.2 Product conceptualisation, through recorded interviews. The requirements materialised in Pilot Definition Plans V1-V3, one for each pilot. End-user requirements are currently evaluated by external stakeholders, identified and contacted by pilot partners as part of the validation procedure. Common Services responds to the pilot cities needs for data representing future climate and air quality conditions.

SUDPLAN Common Services are based on regionally downscaled climate scenario simulations covering Europe and will output further downscaled climate scenario data over specific urban areas. Common Services output will have the spatial and temporal resolution needed to serve as input to local model applications in pilot cities as well as in other European cities.

This report documents the technical solutions of the Common Services software. Section 2 gives an overview of the components, divided into:

- Model systems and databases: Methods, models used and input/output data for rainfall, hydrological and air quality downscaling (details in Section 3).

- The so called back-back end layer: The abstraction layer between the service layer and the implemented models and databases. The Common Services back-back end uses two technical platforms, the Airviro system for rainfall and air quality and the HYPE system for hydrology (details in Section 4).

- Service layer: The external port to Common Services uses standardized (OGC) communication service interfaces: SOS (Sensor Observation Service), SPS (Sensor Planning Service), WMS (Web Map Service) and WFS (Web Feature Service) (details in Section 5).

Common Services has been developed and implemented over two phases with deliveries V1 (at m10) and V2 (at m24). In V1, high priority was given to Common Service *Climate scenario information on the European scale*, which is a basic and fundamental service that needed to be functional at an early stage of the project. High priority was also given to *Rainfall time-series downscaling* which is required by the Linz and Wuppertal pilots. Medium priority to be included in V1 was given to *Air quality downscaling* (not critical since both the Stockholm and the Czech pilots could experiment with air quality downscaling through the avialable Airviro web based user interface).

At the time of delivery of this report (m25), most of the Common Services functionalities have been implemented as back-back end services and according to planned schedule. Some parts are fully integrated with the SMS (PanEuropean visualisation, Rainfall time series downscaling, Air Quality downscaling) while others are only working at command-line level (Rainfall IDF curve downscaling, Hydrological downscaling). Two items remain to be implemented at the back-back end level (Air Quality emission grid upload, Design storm generator) during the first half of 2012.

The technical solutions for standardised (OGC) communication between the Scenario Management System (including SUDPLAN user interface) and the Common Services is shortly described in the report, with details collected in five appendices, of which two have not been completed yet as the developments are an ongoing activity. Also, the technical solutions of the Common Services back-back end have been documented in two appendices, one for rainfall and air quality, the second one for hydrology.

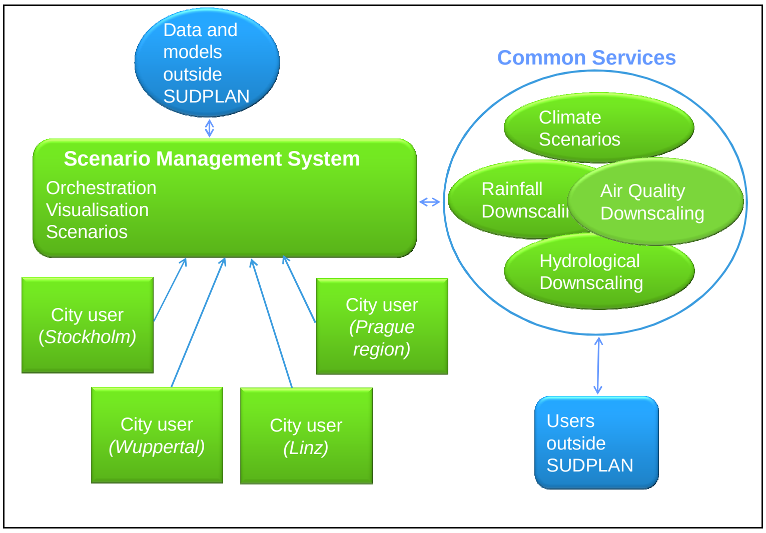
To date two climate scenarios can be used for downscaling in Common Services. Further scenarios will be made available during 2012. A complete list of scenarios available by the end of the project cannot be made today as it depends on the progress of the climate modelling community during 2012, but the intention is to provide a large ensemble, spanning different global models, initial states and IPCC scenarios.

Even though this deliverable is not forseen to have a third version, this report will be updated during 2012 and finally in parallel to the Final Report (D.1.3.3). This update will include aspects of the Common Services that are related to the remaining software developments as well as for more environmental aspects (e.g. a complete list of available climate scenarios).

2 Introduction

SUDPLAN Common Services (CS) aim at facilitating environmental information on the urban scale, in response to a future climate change. It provides interactive climate services, where the user can improve future projections of rainfall, hydrology and air quality by providing certain local data. In SUDPLAN the services will be requested from the Scenario Management System (SMS), which is a model control, visualisation and integration workbench for all SUDPLAN components (Figure 1). The standardized communication will also facilitate an easy setup connection to other software which requires climate services of this type.

Figure 1 Overview of SUDPLAN components. The communication between Common Services and the Scenario Management System uses standardized services (OGC).



This document entitled Common Services Concerted Approach V2 documents the architecture and technical solution of CS components, i.e. the software inside the blue ring of Figure 3. In parallel there are three specific reports for the rainfall, hydrological and air quality downscaling components, which give more details on functionality, methods used for the downscaling and application examples. All documentation related to service and back-back end implementations is however gathered in the present document. The Graphical User Interface is documented in the WP3 deliverable D3.3.2 (Scenarion Management System). The SMS that is the main focus of WP3 work offers user interface functionality for all CS.

2.1 Aim of Common Services

Common Services allow a common urban downscaling functionality for all European cities, based on how relevant environmental factors will evolve according to different climate scenarios. The application of Common Services for downscaling of environmental factors in a new city will be simple and require a minimum of local data, and the results will be communicated through open standards. The following environmental factors are possible to downscale within selected climate scenarios:

- Rainfall intensity, frequency and duration, with consequences for urban storm water flooding and sewer system capacities
- Hydrological conditions in terms of river runoff and soil moisture, with consequences for river flooding, surface water resources and farming conditions
- Air quality with consequences for city population health and life quality

Figure 2 shows how the Common Services (CS) support the local users with downscaled environmental factors, to be used directly on the urban scale or as input to specific local models required by the urban planning process.

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*

Figure 2 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.

2.2 Common Services functionality

The users of SUDPLAN Common Services can select the following options:

- Climate scenario information on the European scale
- Intense rainfall: Time series downscaling, IDF downscaling and Design storm generator
- Hydrological conditions: downscaling of upstream region
- Air quality: Urban downscaling

For Common Services V2 the rainfall and air quality part have been given highest priority. Hydrological downscaling and a few extensions of the air quality and rainfall downscaling will be integrated in the SUDPLAN platform during the first half of 2012.

2.3 Common Services architecture

The technical structure of Common Services is illustrated in Figure 3. The rainfall and air quality downscaling, together with the corresponding Pan-European climate and environmental information, have been implemented in an existing software, the Airviro system. Input and output data is either pointwise time series or gridded time series. The hydrological data is based on pointwise time series and irregular polygon data representing watersheds, managed through the existing HYPE model system. Therefore the back-back end solutions are also splitted in two parts. The service layer does however streamline the communication to all Common Services, so that external user will only have to follow the OGC standards of four services SOS, SPS, WMS and WFS in order to establish communication.

The presentation of Common Services will follow the Figure 3 from bottom to top, starting with model systems and databases, followed by the back-back end layer and finally the service layer which allow an easy setup and standardized communication.

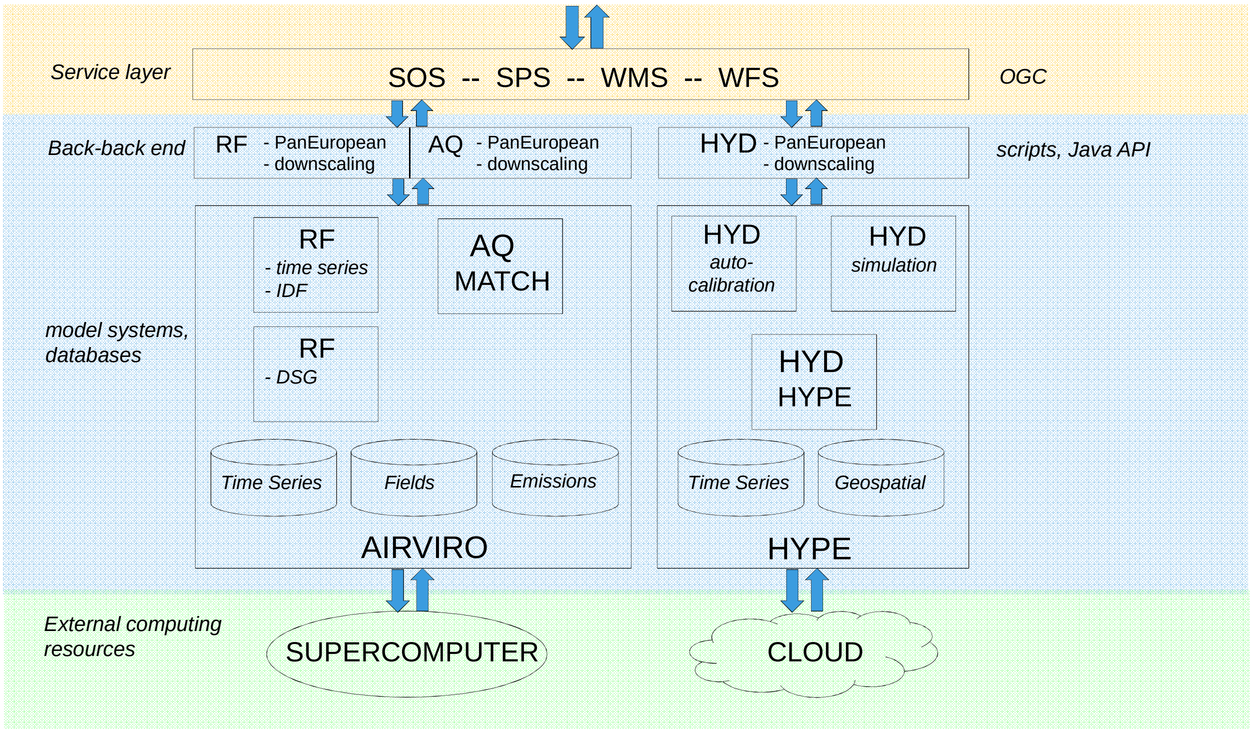


Figure 3 Common Services Layered Architecture

3 Model systems and databases

The following documentation refers to the lower part of Figure 3, describing the rainfall, hydrological and air quality model systems and how they are implemented to provide the downscaling services.

3.1 Model descriptions

This section gives a short description of the models, methods and tools used in Common Services. Not all details are covered, but the references given will allow the reader to get a complete understanding of the CS models.

3.1.1 Climate scenarios

SUDPLAN uses available climate scenarios according to IPCC directed activities preparing for AR4 and currently for AR5 (through the CMIP5 coordinated model intercomparison, see http://cmip-pcmdi.llnl.gov/cmip5). Regionally downscaled results of CMIP5, produced by SMHI, will be available in the end of 2012.

SUDPLAN uses regionally downscaled (over Europe) results from some well reputed global models. For V1-V2 of CS SUDPLAN included the following climate scenarios downscaled by SMHI's RCA3 model (Kjellström et al., 2005; Kjellström et al., 2011; Nikulin et al., 2011):

- ECHAM5 (Roeckner et al., 2006; version: initialization 3), using A1B emission scenario (Nakićenović et al., 2000)
- HADCM3 (Gordon et al., 2000; version: climate sensitivity Q0), using A1B emission scenario (Nakićenović et al., 2000)

In the final version of the Common Services, available at the end of the project, an extended scenario ensemble will be available. Especifically for rainfall downscaling, it is likely to also include the following scenarios:

- ECHAM5 (Roeckner et al., 2006; version: initialization 1), using A1B emission scenario (Nakićenović et al., 2000)
- ECHAM5 (Roeckner et al., 2006; version: initialization 2), using A1B emission scenario (Nakićenović et al., 2000)
- ECHAM4 (Roeckner et al., 1996), using A2 emission scenario (Nakićenović et al., 2000)
- ECHAM4 (Roeckner et al., 1996), using B2 emission scenario (Nakićenović et al., 2000)

The scenarios for air quality may differ also in the emission scenarios for tracers (air pollutants). In Common Services V1-V2 the only time-varying emissionso for 1960-2100 is given by the RCP4.5 scenario.

During 2012 we expect new scenarios, generated within CMIP5 and further downscaled by SMHI, to be completed and ready for use in SUDPLAN. These scenarios may also be of higher spatial resolution. The details of those will be introduced as an update of this public document.

3.1.2 Downscaling of intense rainfall

This section deals with the models used in the downscaling of intense rainfall. The methods differ depending on the type of input data selected by the end-user. The first alternative is input of an IDF curve, the second a time-series and the third a design storm.

3.1.2.1 IDF curve downscaling

The IDF curve downscaling is based on extreme value analysis of annual rainfall maxima of different durations using the Generalized Extreme Value Type 1 (Gumbel) distribution, as outlined in e.g. Wern and German (2009). For the selected climate scenario, the analysis is applied to time series of 30-min precipitation in one reference period (for which is attributed the IDF statistical characteristics) and one future 30-year time period, both specified by the user. Time series from five model grid points surrounding the desired location are analysed in order to reduce statistical uncertainty. For a certain scenario, the following steps are included:

- Calculate annual maxima for durations 30 min, 1 hr, 2 hr, 3 hr, 6 hr, 12 hr and 1 day for both time periods in all five grid points.

- Fit the EV1 distribution to all sets of maxima, i.e. for each time period, grid point and duration separately.

- From the fitted EV1 distributions, calculate rainfall intensities corresponding to all durations and the return periods 1, 2, 5, 10, 25, 50 and 100 years. Make averages over all grid points.

- Calculate relative changes in rainfall intensities between the reference period and the future period, for all durations and return periods.

- Perform multiple linear regression to express the change as function of duration and return period. This step is required to reduce the statistical scatter.

- Apply the estimated relative changes to the user-uploaded IDF values and make it available for download.

3.1.2.2 Time-series downscaling

Time-series downscaling is based on the version of the general Delta Change (DC) method described in Olsson et al. (2009). Essentially, short-term precipitation from climate scenarios are analysed in order to estimate future changes associated with different intensity levels in the frequency distribution. As in the case of IDF downscaling, the analysis is applied to time series of 30-min precipitation in one reference period (for which is attributed the statistical characteristics of the measured precipitation time series) and one future 30-year time period, both specified by the user. Time series from five model grid points surrounding the desired location are analysed in order to reduce statistical uncertainty. For a certain scenario, the following steps are included:

- Calculate percentiles of the precipitation intensity distribution for both time periods in all grid points.
- Calculate so-called DC factors as the ratio between integer percentiles in the reference period and in the future period, respectively.
- [If required, convert the user-uploaded time-series to a 30-min time resolution.] Analyse the user-uploaded time-series to associate each 30-min time step with a certain percentile.
- Apply the estimated DC factors to the uploaded time-series and make it available for download.

In addition, an option to use frequency adjustment will be implemented. Using this option, it is possible to modify not only the rainfall intensity frequency distribution in line with the expected future changes, but also the frequency of occurrence of dry and wet (i.e. rainy) periods. This is based on removal or multiplication (‘cloning’) of representative rainfall events in the historical series, to adjust the frequency of occurrence to fit the expected future occurrence.

3.1.2.3 Design storm generator (static and dynamic)

The intention is to simulate the movement of a rainstorm over an urban catchment and generate consistent time-series in selected locations. The generator is based on the concept of a design storm, i.e. an idealised time-series of rainfall intensity during an intense event (e.g. Shaw, 1983). In the Design storm generator (DSG), a historical design storm is modified using the expected future change of rainfall intensities corresponding to the relevant combination of duration and return period. This change may be estimated using the IDF downscaling above.

Two versions of the DSG is available, a static and a dynamic. The static corresponds to a traditional design storm, where the same intensity is applied in the entire catchment on a certain time step. In the dynamic version, the design storm is translated over the catchment to simulate storm movement, which may be important (e.g. Niemczynowicz, 1984). The implementation of the dynamic DSG essentially follows the principles outlined in Vaes et al. (2002). For a certain scenario, the following steps are included:

In the static case, the intensity during each time step of the historical design storm is multiplied by the expected relative change

- [static and dynamic] Downscaled design storm is generated by multipliying the intensity during each time step of the historical design storm by the expected relative change.
- [static] Make downscaled static design storm (single time series) available for download.
- [dynamic] Calculate the time lag for different parts of the catchment, using the user-selected storm direction and assuming a default storm speed.

- [dynamic] Generate historical and downscaled dynamic design storms (space-time matrices) by appropriate time lagging of the static design storms, make available for download.

3.1.3 Hydrological model E-HYPE

The Hydrological Predictions for the Environment (HYPE) model is a dynamic, semi-distributed and process-based model based on well-known hydrological and nutrient transport concepts (Lindström *et al.* 2010). It can be used for both small and large scale assessments of water resources and water quality. In the model, landscape is divided into classes according to soil type, vegetation and altitude. The soil representation is stratified and can be divided in up to three layers, each with individual characteristics and hence calculations. The model simulates water flows, transport and turnover of nitrogen, phosphorus and inert trace substances. These substances follow the same pathways as water in the model: surface runoff, macro pore 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 specific characteristics of Hydrological Response Units (HRU), i. e. combinations of soil type and land-use. Internal model components are checked using corresponding observations from different sites (Arheimer *et al.* 2011).

The HYPE model code is structured so that the model can be easily applied with high spatial resolution over large model domains, which is also facilitated by linking coefficients to physical characteristics and the multi-basin calibration procedure (Donnelly *et al.* 2009). So far, the HYPE model has been applied to simulate hydrological variables for all of Europe (E-HYPE1.0), and nutrient and hydrological variables for all of Sweden (S-HYPE) and the Baltic Sea basin Balt-HYPE). Large-scale applications of the HYPE model are possible due to the ready availability of regional and global databases, which are handled in a specially designed system of methods for automatic generation of model input data, WHIST (Strömquist *et al.* 2009).

To investigate uncertainties it is important that model calibration and validation is performed for specific variables and with the resolution in time and space that will be used by the enduser. The model is not calibrated site specifically, but simultaneously for groups of parameters referring to different parts of the model structure. This makes the model robust for large regions although specific sites may not be simulated as well as if local calibration is applied. Proxy-basin tests are used to investigate whether the model results are valid in ungauged basins and data sparse regions.

In this second pan-european application of the HYPE model, E-HYPE 2.0, subbasin delineations have been updated to a median resolution of 215 km^2 using more information about real catchment boundaries where available and using a database of wetlands and lakes to ensure these are encapsulated by a subbasin where necessary. The model application was also calibrated to 80 gauging stations across Europe and validated to a further 860 stations. In calibration and validation, an observed time-series of daily discharge is compared to a time-series of simulated daily discharge at the same point in the model. Further improvements in E-HYPE 2.0 include detailed information for 166 of the largest lakes in Europe, specific rating curves and regulation routines for many of these large lakes, the use of quantitative evapotranspiration data for Europe and an updated glacier routine.

In the Common Services tool, the local user can select their basin of interest from the pan-European model and may add their own extra observed time-series of water discharge at a point within this basin. It will then be possible to run a simple automatic calibration routine for this domain to improve on the results from the pan-European model. The user can then select climate scenarios which have been dynamically downscaled and bias corrected (Yang *et al.* 2010) to fit with the hydrological modelling on the local scale. The user can then run the model in the new SUDPLAN interface, which then displays the results as visualisations of future risks of droughts or 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 (according to the procedures of Donnelly *et al.*, 2009), 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.

3.1.4 Chemical Transport Model MATCH

MATCH is an Eulerian off-line chemistry-transport model (CTM) developed at SMHI. A comprehensive description of the model structure, boundary layer parameterization and advection scheme etc. is given in Robertson et al. (1999). The photochemical scheme, based on Simpson et al. (1993), includes ca. 70 chemical species and around 130 chemical reactions. It is detailed in Langner et al. (1998), which also provides 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. Tilmes et al., 2002; Solberg et al., 2005a; 2005b; Vautard et al., 2006; van Loon et al., 2007; Andersson et al., 2007).

Since MATCH is an off-line model it requires three-dimensional meteorological forcing from an external driver. A number of recent studies have utilized MATCH together with climate data from the Rossby Centre regional climate model (e.g. Hole and Engardt, 2008; Engardt et al., 2009; Andersson and Engardt, 2010; Klingberg et al., 2011).

In the first set of Pan-European air quality simulations for SUDPLAN emission data from the RCP4.5 inventory (Thomson et al., 2011) have been used to describe the evolution of tracer emissions over the European continent from 1960 up to 2100. The RCP4.5 data is available for every 10 years, but linearly interpolated to 1 year resolution for the CTM simulations. Sub-annual and sub-daily temporal variations are specified, in the CTM, based on emission type. For the urban pilots (e.g. Engardt et al., 2011), locally provided emissions data are used. These data come on 1-hour resolution and are divided between area sources and large point sources; in MATCH the emissions from the large point sources take place at the height specified for the each stack.

3.1.5 Other model components supporting CS functionality

As much of the input and output data of Common Services is stored in Airviro databases, it will also be possible to use the Airviro processing package which has tools for combining data with arithmetic expressions, averaging, extraction etc of both pointwise time-series as well as times-series of gridded field data. The web based user interface of the Airviro system has been extensively used for pilot experimentation with downscaled data of the air quality use cases.

3.2 Components and functionality

SUDPLAN provides planning, decision support and training tools that help decision makers and planners to evaluate how different environmental conditions and problems on the urban scale will evolve under a changing climate. Common Services offer urban downscaling services for intense rainfall, hydrological runoff and air quality. Common Services represents a common functionality to be used by all four SUDPLAN pilot cities and can be applied in all European cities. SUDPLAN pilots focus on different parts of SUDPLAN climate downscaling services:

- Stockholm: Air quality
- Wuppertal: Intense rainfall, surface flooding
- Linz: Intense rainfall, sewer overflows
- Prague: Air quality and hydrological conditions

Common Services provide input to the pilots according to this list. In subsections 3.2.1-3.2.4 below, the functionality of each Common Service is outlined. In the final subsection (3.2.5), the prioritised order of implementation is outlined.

3.2.1 Climate scenario information on the European scale

The opening page of the Common Services tool is a map over Europe, on which some basic European-scale information (after regional downscaling, without urban downscaling) can be displayed. The following services will thus be available for ***all pilots***, allowing them to compare trends in climate and environmental variables in their city with the rest of Europe, thereby contributing to the training objective. The following information can be visualized:

<u>Climate scenarios:</u> A list of available and selectable climate scenarios given separately for climate (precipitation/temperature), hydrological variables and air quality.

<u>Format</u>: 10-year averaged grids or polygons for the period covered by the regionally downscaled climate scenarios (currently centered 1965-2095). Results are displayed over a map, with a simple control to go backward and forward in time.

End-users are able to locate a receptor point on the map and produce a parallell (to the map presentation) time-series graph from that location. The plotted time series can be specified as 10-year, yearly, monthly or daily averages.

The following variables are possible to visualize on the European scale:

<u>Climate variables:</u> Precipitation and temperature (grids).

<u>Hydrological variables:</u> Presented as averages for individual watersheds: Discharge (accumulated runoff), specific runoff (local runoff from individual watershed), soil moisture (relative value), groundwater (relative level) plus the DBS corrected temperature and precipitations. There are also some statistical output (only 30-year averages): the 1 in 10 year and 50-year floods, mean annual high water discharge, mean annual low water discharge,

number of days with hydrological drought, number of days with agricultural drought, intensity of days of agricultural drought, snow storage potential and maximum snow depth.

Air quality pollutants: O3, PM10, NO2 and SO2 (grids).

3.2.2 Intense rainfall

Intense short-term rainfall for future climatic conditions can be simulated by Common Services, if the user provides historical precipitation data, either as high resolution time series or as statistics. The following service will be used intensively for the ***Wuppertal and Linz pilot*** and is of interest for the ***Stockholm pilot*** as well.

3.2.2.1 Rainfall downscaling

The Common Services opening page is a map over Europe which can be zoomed in over a particular city. End-users have a possibility to access a more detailed map for their SUDPLAN city.

Climate scenarios: A list of available and selectable climate scenarios is shown.

City-specific input data can be given according to two alternatives, for which the formats are:

Format of user input alternative 1: Intensity Duration Frequency (IDF) values from the city, given as a table of rainfall intensities (I) related to different durations (D, lower limit 30 min; upper limit 1 day) and return periods or frequencies (F, lower limit 1 year; upper limit 100 years). The number of table entries can be one (one duration and one return period) or more (multiple durations and/or multiple return periods). Together with the uploaded values, a representative 30-year period must be given, i.e. the historical 30-year period that best represents the observations from which the IDF values have been derived. The first selectable starting year is 1961 and the last selectable ending year is the current year.

Format of user input alternative 2: Continuous historical time-series of precipitation from e.g. a tipping bucket or similar high resolution instrument (text file with two columns: time stamp and rainfall volume). The time resolution can be varying (e.g. raw tipping-bucket registrations) or fixed (e.g. tipping-bucket data aggregated to a fixed interval) but should be 30 min or higher. The time series is assumed to span several years (Linz will have 30 years of data) with all seasons represented. The time series is automatically associated with a representative 30-year period, centred on the center of the uploaded series but restricted between 1961 and the current year. The station should be located on the map or specified with coordinates.

The output format will depend on the input alternative:

Output from alternative 1: Both historical and future simulated IDF values are returned, where the latter represents a selected future 30-year period. Example: The historical values represent 1981-2010, the output values represent e.g. 2071-2100.

Output from alternative 2: Historical and future simulated time-series, where the latter represents a selected future 30-year period. Example: The historical time-series represents 1980-2010, the output time-series represents e.g. 2071-2100. Graphs of the series may be displayed at as 30-min values with possibility to zoom in on individual events. The future simulated timeseries can be exported to a text file in the same format as the historical time series (this is what Wuppertal and Linz pilots will use as input to their local applications).

3.2.2.2 Design storm generator

The IDF downscaling (alt. 1 above) is further complemented with a Design storm generator (DSG), which may be used to produce a design storm (i.e. standardized rainfall event time series). This is a commonly used concept in the design of the components in urban storm water drainage systems (e.g. Shaw, 1983). In engineering practice a single design storm is used for an entire urban catchment (static design storm) and in the DSG it will be possible to upload a historical design storm and have it downscaled. Further, a space-time extension is developed in the DSG, making it possible to generate different but consistent design storms for different parts of the catchment (dynamic design storm), taking storm extension, direction and speed into account.

This Common Service needs an estimation of how the volume of intense rainfall events will evolve due to expected changes in climate variables. This can be estimated by using the IDF downscaling service or by using information from other sources (reports, guidelines, etc.). The generated time-series (in a point or as a grid) grid can e.g. be used as input to local sewage water system models. The service will be available for ***all pilots***, as the local input is limited to two, commonly known meteorological values (see below).

The Common Services opening page is a map over Europe which can be zoomed up over a city and on which an urban domain can be defined.

Climate scenarios: A list of available and selectable climate scenarios will be shown.

Format of user input: Historical design storm (text file with two columns: time stamp and rainfall volume). The time resolution can be varying or fixed. The end-user should further define the geographical domain (rectangle) over the city and a grid within this domain. A grid with only one cell implies generation of a static design storm; a grid with multiple cells a dynamic design storm. Two parameters should also be given: (1) total volume of the design storm in future climate (typically taken from an IDF curve) and (2) storm direction ((2) only for dynamic design storm).

Output, alternative 1 (static design storm): Both original and future simulated design storms are returned. The future simulated design storm can be exported to text files on the same format as the historical design storm. Bar graphs with both storms may be displayed.

Output, alternative 2 (dynamic design storm): Both original and future simulated design storms are returned; one series for each cell in the selected grid. Both original and future simulated dynamic design storm can be exported to text files with time step as rows and grid cells as columns. It is intended to develop functions for viewing both original and future simulated dynamic design storm as an animated 3-D sequence.

3.2.3 Hydrological conditions: local downscaling

Common Services allows the user to produce improved hydrological model results (as compared to the pre-calculated E-HYPE results) by using additional local information that may be available (e.g. river discharge measurements) and optimizing the model calibration to the available local river discharge stations. The following service is heavily used for the ***Czech Regional pilot***.

The first aim of the service is to provide hydrological predictions on a Pan-European scale calculated using climate predictions as inputs. The second aim of the service is to provide an easy to use downscaling service where the end user can improve and adapt climate prediction data to local measurements. An important aim in defining the service has been to minimize the required user input. Two types of user specifications are needed to launch a model simulation, the downstream point of interest on waterway and the climate scenario to be used as input, with a third option given to add user data for model calibration.

The opening page of the Common Services tool for hydrological data is a map over Europe which can be zoomed to the region of interest (Zoom level 1). Note, however, that because hydrological conditions in a city are affected by the catchment upstream, it is alsopossible to zoom to the catchment upstream of the point of interest. (Zoom level 2). Hydrological conditions are simulated for all of the upstream area (Zoom level 2); however, Zoom level 1 is 'the selected area' for which hydrological conditions resulting from the simulation will be displayed. Based on the selected area the locations of existing calibration stations, metadata for these stations, and time-series graphs can be shown.

The hydrological downscaling is performed by creating a sub-model of the Pan-European hydrological model, E-HYPE, for the river or stream running through the specific city or region of interest and the catchment upstream of the point of interest on this river or stream. From the SMS, the user can run an automatic calibration of the model to optimize model parameterization for this catchment. The users can also opt to add their own measured discharge data, if available, to improve this calibration. Once the new, local hydrological model is calibrated, it can be used to perform simulations based on selected climate scenarios. Note that unlike the other downscaling services, the spatial resolution of the output remains the same at European and local scales (i.e. the watershed and subbasin definitions of the downscaling application will be the same as for the Pan-European model). It is the calibration with local data that will improve the quality of the downscaled model output.

In the Czech Regional pilot definition plan V2 (D8.1.2) two use cases have been defined that describe the main functionality of the hydrological downscaling service. In the present document we will use these use cases as the basis a description of the service functionality.

- Use case UC-832: Auto calibration of CS hydrological model

  This use case describes automatic calibration of the CS hydrological model for one point in the map. The goal of the service is to provide improved simulation results for upstream watersheds. The user has the option to provide a discharge data time-series from a selected gauging station or even to use existing stations. The results of the service are new parameter sets that can be used for subsequent runs of the CS hydrological downscaling, with an improved hindcast of discharge at the site using the new parameter set.

- Use Case UC-833 “Execute CS hydrological model”

  In this use case the user wants to execute the CS hydrological model to simulate the hydrological conditions for future climate scenarios for the upstream area of the selected point of interest (POI). Auto calibration (previous scenario) should have been performed for the same upstream area before this step. The goal of the service is to provide an analysis of the effects of future climate on hydrological conditions, based on a CS climate scenario. The hydrological model uses precipitation and temperature (P, T) as input data from the climate projections as well as the newly calibrated parameter set. The outputs are maps of hydrological states as well as time-series of hydrological variables for the subbasins upstream of the point of interest.

Output: River discharge, local runoff, relative soil moisture, relative groundwater level, DBS-corrected temperature and DBS-corrected precipitation, all available as daily/monthly/annual/10-year averarages.

A more detailed description of the service is given in D4.3.2 Hydrological downscaling service V2.

3.2.4 Air quality: urban downscaling

Common Services allows the user to produce downscaled air quality on the basis of local emission data. This service is heavily used in the ***Stockholm and Prague pilots.***

The Common Services opening page is a map over Europe which can be zoomed in over a city and on which an urban grid can be defined.

Climate scenarios: A list of available and selectable climate scenarios is shown.

Format of user input: End-user should provide gridded (1×1 km^2) and point source emissions, given as yearly averages of NOx, NH3, PM, SO2, VOC and CO. In addition to this, the time variations - monthly and daily - of the emission grids should preferably be specified (if not, standard variations is used). The local emission scenario should represent a specific year, e.g. “present” or “future” conditions. An air quality downscaling will use this emission database for the entire period, which means that “present” and “future” simulations are executed separately.

Output: The CS model MATCH generates simulation results for NO2, NOx, O3, SO2 and PM10 (hourly, daily, monthly and annual averages) for year long periods within the period covered by available climate scenarios (presentently 1960-2100). End-users are able to create and display differences between two different grids (e.g. difference between 2050 and 2010 or between the same year of two different scenarios). A simple control to go simultaneously backward and forward in time for both grids is available.

End-users have possibility to select the preferred time resolutions, i.e. present annual, monthly, daily averages and hourly averages of air pollutant grids. It is also possible to present differences of CS results, e.g. of two simulations using different climate scenarios. Another user option is to locate a receptor point on the map and produce a parallel (to the map presentation) time-series graph from that coordinate, covering the displayed period. End-users are able to export receptor time-series data, to be used as boundary data to local models.

3.2.5 Prioritised order of implementation

Table 1 describes the priorities for the Common Services functionalities with respect to back-back end implementation during the final year (integration into SMS user interface is not indicated here, as this topic is covered in separate WP3 deliverables D3.3.x Scenario Management System). Items 1-5 in Table 1 have been completed in the latter part of 2011. At the time of this report (Jan 2012), the functionalities related to the hydrological features of Pan-European visualisation is being implemented. Two Common Services functionalities have been moved to 2012; the upload of emission grids to support Air Quality downscaling and the Design Storm Generator. Concerning the latter, the model component is complete but the back-back end implementation remains to be done. This is expected to be straight-forward as procedures and solutions required are similar to the functionalities already implemented for CS air quality and rainfall downscaling.

Table 1 Priorities of components to be implemented in Common Services

Priority	Functionality to be integrated in CS	CS status (back-back end)
1	Pan-European visualisation ”Climate & Air Quality”	Done
2	Rainfall time series	Done
3	Rainfall IDF	Done
4	Air Quality downscaling (no emission upload)	Done
5	Hydrology calibration & model execution	Done
6	PanEuropean visualisation ”Hydrology”	Ongoing
7	Air Quality: emission grid upload	Start 2012
8	Design Storm Generator	Start 2012

3.3 Technical solutions

Most of the climate scenario data that we will use (see Figure 2) must be, in one way or another, preprocessed to fit as input to the Common Services models. In other words, direct output from the Rossby Centre RCA model is insufficient to interpret the effects of climate changes at the urban scale. The Common Services needs to contain data concerning the impacts of climate scenarios on rainfall data, climate hydrology and air quality downscaled to the urban scale. For example:

- Rainfall: To interpret the expected extreme intensities of rainfall in cities, the intensity of the RCA rainfall needs downscaling using 30 min data (normally not in public output)

- Hydrology: To interpret the impact of climate change on hydrology, the HYPE hydrological model has to be run using climate scenario data as input

- Air quality: To interpret the impact of climate change on air quality, the MATCH atmospheric chemistry model has to be run using climate scenario data as input

For Common Services the possibility to visualise results for various climate scenarios - the variables precipitation and temperature - is provided. One issue is that, for example, the frequency distribution of temperature and precipitation from standard output of RCM models (like the SMHI regional climate model RCA) do not match observed distributions for a control period. Consequently these variables have to be subject to some corrections before hydrological downscaling with the Common Services model HYPE. The corrections follow the DBS method (Yang et al., 2009). Both corrected and non-corrected temperature and precipitation will be available for visualisation.

Other environmental data on the European scale, e.g. the air quality and the hydrological variables, used as input to the SUDPLAN downscaling or for direct display over Europe, must be pregenerated at SMHI and stored in the Common Services databases. If we later want to use other climate scenarios than those of SMHI's RCA model, such data must first be preprocessed. Consequently it will not be possible for an external end user to connect to an arbitrary climate scenario and then start Common Services downscaling.

Huge amounts of data are accessible in Common Services and huge amounts will also be generated during the downscaling. Although raw output will be stored with high temporal resolution (e.g. 30-min grids of precipitation), the Common Services user will likely generally request aggregated data, e.g. 10-year average fields. Thus Common Services allow rapid access to the highest resolution available, as well as to lower time resolutions.

3.3.1 Selection and storage of climate scenario data

The underlying, original, meteorological data describing the evolution of climate in the different scenarios are taken from already completed model simulations by the RCA model. Each climate scenario represents a possible realization of climate change. There is no scenario that is "*the most likely*"; several scenarios must be used to explore the uncertainty in the evolution of climate. The different scenarios are valid under the assumptions of the respective scenario. Typical assumptions concern future atmospheric concentrations of CO_2 (i.e. IPCC emission scenario) and other climatically active species, or different global or regional model formulations.

In V2 of the Common Services we use two different climate scenarios (data-sets) to explore the impact of different global models on the boundaries of the regional climate model. The global models used are ECHAM5 (Roeckner et al., 2006) and HadCM3 (Gordon et al., 2000). Both scenarios assume the same climate forcing (i.e. the IPCC A1B emission scenario coupled to a certain carbon cycle model) to achieve atmospheric concentrations of CO_2. In both cases, regional downscaling has been performed by the RCA model. Thus, in V2 only the uncertainty related to GCMs may be assessed, but also other uncertainties (RCM, IPCC scenario etc.) may be taken into account later on by providing a larger set of scenarios, as discussed above. It may be mentioned that the uncertainty related to GCMs is often found to be the dominant one, thus it is sensible to focus on this in V2.

The amount of information in the climate data-set is large. Each climate scenario consists of three-dimensional meteorological information over Europe on approximately 44 km × 44 km horizontal resolution. Data is available at regular instances each day during a ~140 year period. The (compressed) raw data occupies ca. 3 GB per year. The two aforementioned climate scenarios thus require almost 1 TB of disk space. These data are stored in the Common Services databases at SMHI.

3.3.2 Common Services databases at SMHI server

Common Services must be able to store a huge amount of model output, both pre-calculated climate, hydrology and air quality on the European scale as well as downscaled data over SUDPLAN cities, generated directly by the users. The technical characteristics of the CS databases are given here below.

3.3.2.1 Time-series data (climate, air quality)

The time-series data to be stored are:

- Short-term rainfall (two possible time formats: (1) continuous series with fixed time step *s* where s≤30 and, if s<30, 30 is divisible by *s* or (2) time stamp (minute or second))

- Runoff, precipitation, temperature (daily)

- Air quality, meteorology (hourly, daily)

The technical solution for rainfall and air quality time-series data is stored in the Airviro time-series database. The Airviro Time Series database (AVDB) is a highly optimized database especially designed for storing synchronous time series data. It is based on the FairCom CTREE database, using only the ISAM[1] level for full control and fast access (Figure 4).

Currently a number of base time resolutions are supported: 1 s, 1 min, 5 min, 10 min, 15 min, 20 min, 30 min, 1 hr, 1 day. There is also a processing package that provides a number of features:

- On-the-fly accumulation (min, max, average, percentiles, etc) to various new time resolutions, e.g 8-hours, month, year, etc.
- Combining time series with arithmetic expressions.
- Running averages.
- Statistical tools.

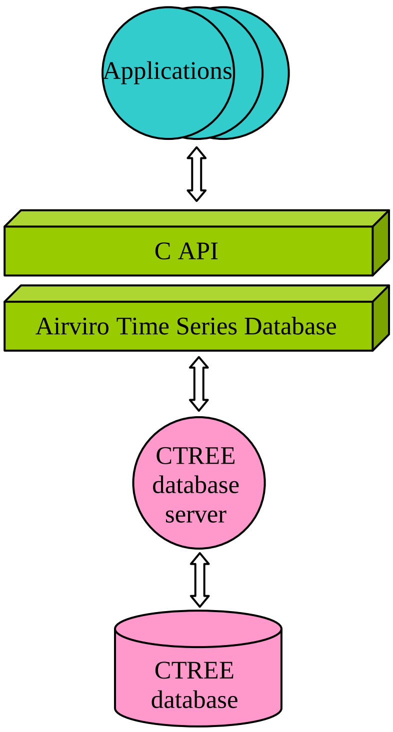


Figure 4 Schematic design of the Airviro time-series database (C API stands for Application Programming Interface written in C)

[1] Index Sequential Access Method

3.3.2.2 Gridded atmospheric emission data

The downscaling of air quality through dispersion modelling requires a fast access to emission data. Moreover the emissions, like the dominant traffic source, will vary over time. The SUDPLAN end-user will upload to a database at the Common Services server emission grids together with some tables that describe time variation for different hours of the day and for different parts of the year. During dispersion model execution hourly emission grids will be extracted as input to the air quality dispersion model MATCH.

Common Services will use the Airviro Emission database (EDB), which is a complex database specifically designed for storing emission sources, their variations and emission factors with focus on fast emission calculations for dispersion modelling etc (Figure 5). Emission calculations can produce time series of gridded emission fields for display or as input to dispersion models.

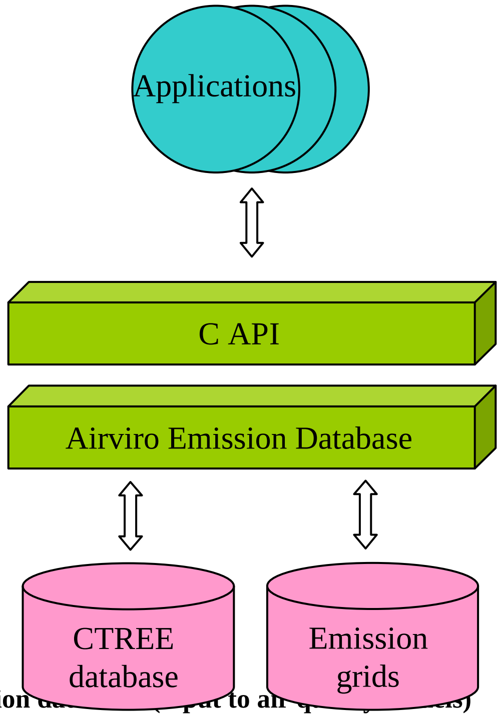


Figure 5 Schematic design of emission database (input to air quality models)

3.3.2.3 Gridded air quality data

Regional modelling of air quality on the European scale, like the urban downscaling simulations, will be performed on the computational servers of SMHI. The European scale simulations include a (e.g. 5 to 30 year) historical period based on observed meteorology from HIRLAM or ECMWF to facilitate comparison with real-world measurements and also analyses of different climate scenarios to explore future concentrations of pollutants in the atmosphere.

The results of the regional air quality simulations consist of three-dimensional time-series, every 1 hour, of 60+ atmospheric species. Three-dimensional fields of most species are needed as boundary fields for the higher resolution urban simulations. For the evaluation and visualisation of the air quality results, only a subset of the complete data-series will typically be relevant. Less than 10 atmospheric species will be of interest for most users and in most cases only surface concentrations will be of interest.

The three-dimensional time-series on the European scale consist of huge data-sets. One year is ~300 GB of highly compressed data (GRIB[2]-format). A 140 year climate scenario realization will be ~50 TB data. This vast amount of data will be temporarily stored at SMHI's servers and used as input to the urban downscaling simulations. The results of the, higher-resolution, urban simulations will not be as comprehensive as the regional scale data, as it is not necessary to store all model variables at all model levels (as the data will not be used as boundary conditions to new model runs). One year of high-resolution air quality data over a certain city will consist of two-dimensional time-series of ~10 different variables. The size of this data is ~2 GB per year (in GRIB-format).

As the display of air quality over Europe requires a rapid access and postprocessing, it is necessary to store a subset (two-dimensional fields of ~10 species) of the European scale results also on the Common Services server, in Airviro. The downscaled air quality results over a particular city are also transferred from SMHI super computer servers to the Common Services server, so that they are available visualization and time series output.

The Airviro Field database (RNB) is a database specifically designed for storing asynchronous and synchronous single or time series of scalar or vector fields (Figure 6). Fields can be stored compressed or uncompressed. There are indexes for fast access to single fields in a time series and also a special index for fast access to time series of receptor point values from a time series of fields.

[2] GRIdded Binary

There is also a processing package with tools for:

- Combining multiple fields and/or time series of fields using arithmetic expressions.
- Spatial cuts and re-sampling of fields or time series of fields.
- Processing of statistics from time series of fields:
  - Averages
  - Percentiles
  - Minima
  - Maxima
  - Exceedances
  - Running averages
  - Daily averages
- Extraction of time series of receptor points from a time series of fields.
- Split/join of time series of fields.

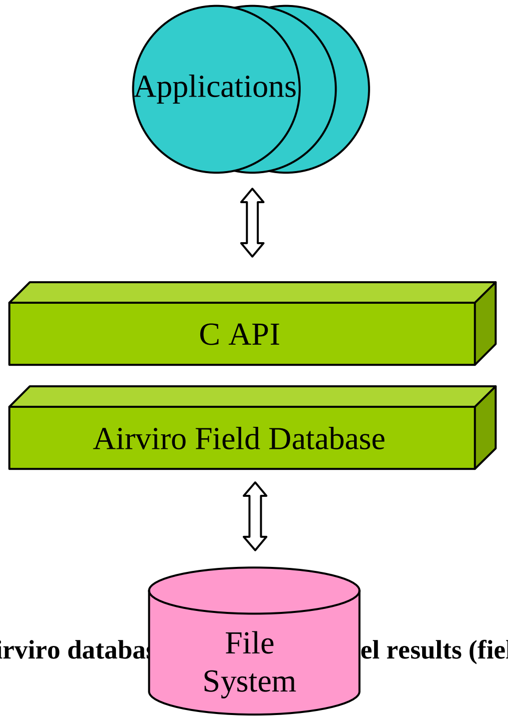


Figure 6 Schematic design of the Airviro databa el results (fields)

3.3.2.4 Hydrological data

For the assessment of hydrological impacts, two types of hydrological data are made available:

- a data library of pre-calculated results for the entire European continent (E-HYPE)
- results from interactive re-runs for selected urban areas including the catchment area upstream of the point of interest (also referred to as downscaled results)

Our solution offers two possibilities for storage of data a geospatial and a time series repository. The geospatial repository is tailored for storing maps and the specialised time series repository that allows fast access to time series data. In particular, this solution implements a fast and efficient storage of E-Hype data files. This is, in particular, interesting for the storing of downscaled input data and results of interactive runs allowed by the downscaling service in SUDPLAN.

For the SUDPLAN system original watershed static data over Europe will be stored in the geospatial repository, where maps are easily represented. Dynamic data, generated by the end users simulations, require a fast access time-series data and are insteade stored in the time series repository (Figure 7).

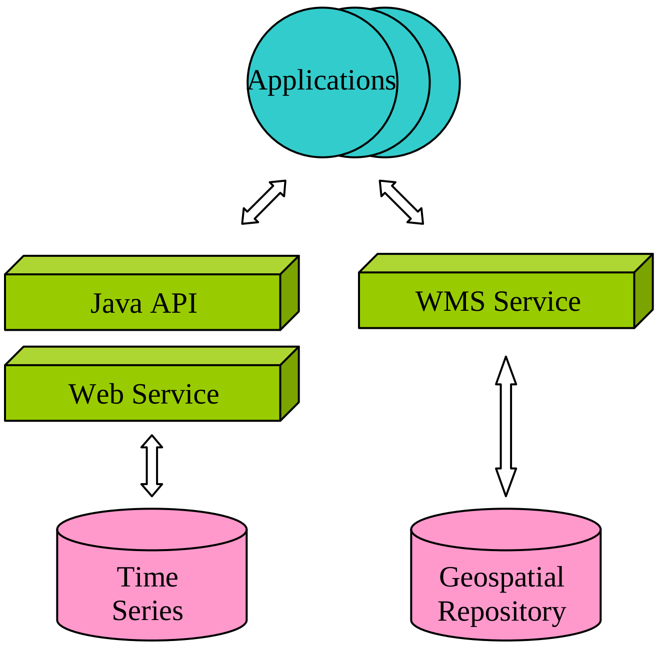


Figure 7 Schematic design of the data storage used for hydrological data

4 Back-back end of Common Services

This section describes the technical solutions for the abstract layer between the CS model systems and the service layer. For each CS component there is also a more extensive documentation of the back-back end solutions to be found in Appendices 3-7.

4.1 Climate scenario information on the Pan-European scale

The following list and figure indicates the services and data flows that are required to fulfill the CS use as specified in Sections 3.2.1 Climate scenario information on the Pan-European scale.

List of Services required:

- Listing of Climate Scenarios (climate, hydrology, air quality).
- Access to ime series of fields (typically 10-20 fields per parameter, one field for every 10 years or for some statistical data fore every 30 years). These fields are averages over a 10/30 year periods.
- Get single fields representing the difference between two 10/30 year periods (e.g. 2050 and 2000).
- Get single fields representing the difference between the same time period but for two different scenarios.
- Get time series representing a receptor point in the running 10/30 year period averages (10/30 year, yearly, monthly or daily resolution on the resulting time series).

Data flow

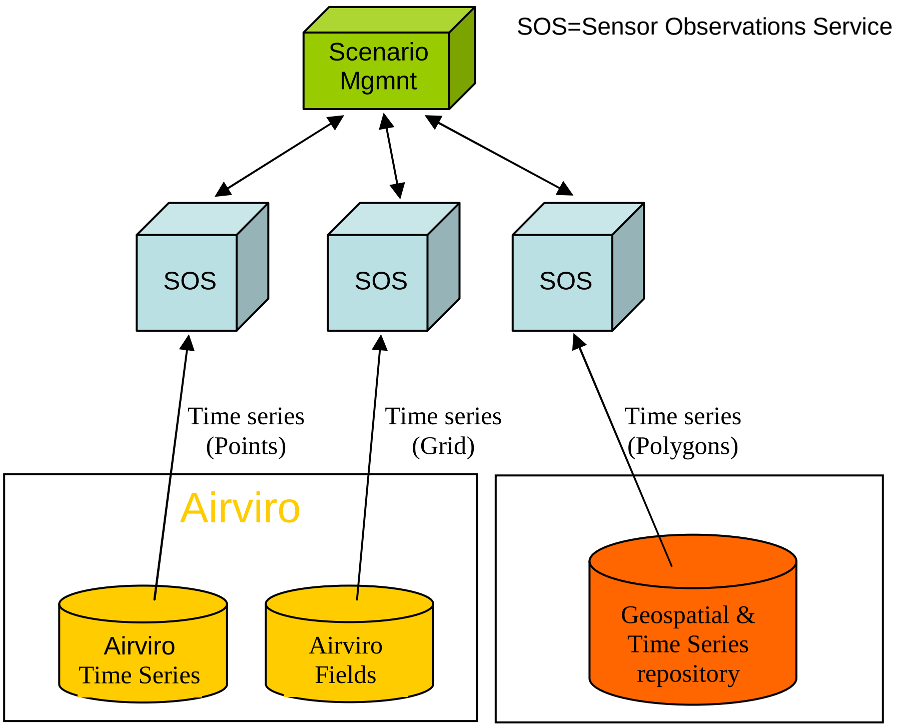


Figure 8 Components, databases and data flows for climate scenario information on the European scale

Technical solution for the back-back end

More details on the technical solution of the PE (information on the Pan-European scale) implementation in the Common Services (back-back end) are found in Section 1.2 of Appendix 1 (rainfall and air quality) and Section 1.2 of Appendix 2 (hydrology).

4.2 Intense rainfall on the urban scale: local downscaling

The following list and figure indicates the services and data flows that are required to fulfil the CS use as specified in Section 3.2.2. Intense rainfall.

Services:
- Listing of Climate Scenarios.
- Model service for taking a locally measured precipitation time series from the SMS and calculate a corresponding time series for a future climate scenario.
- Model service for taking a current IDF curve from the SMS and calculate a corresponding IDF curve for a future climate scenario.

Data flow:

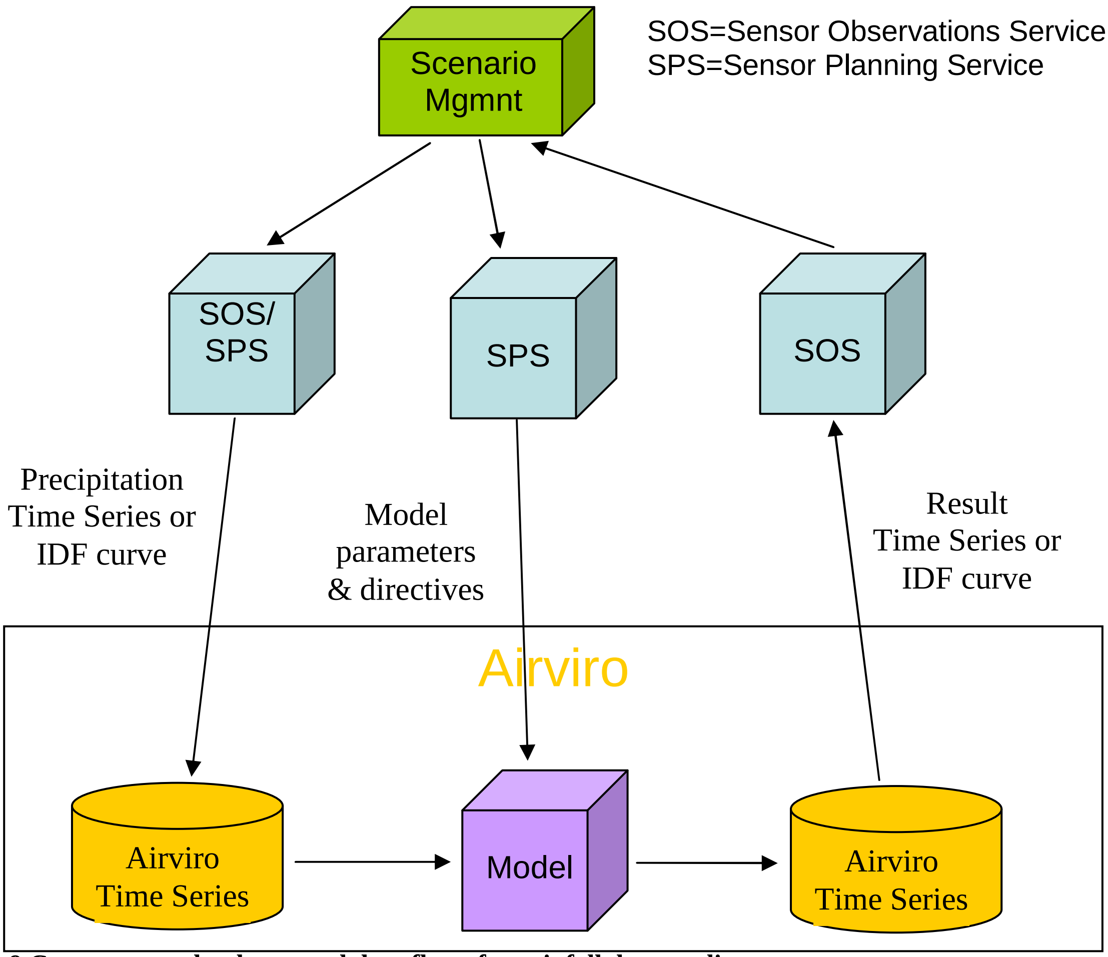


Figure 9 Components, databases and data flows for rainfall downscaling

Technical solution for the back-back end

More details on the technical solution of the RF (RainFall downscaling) implementation in the Common Services (back-back end) are found in Section 1.3 of Appendix 1.

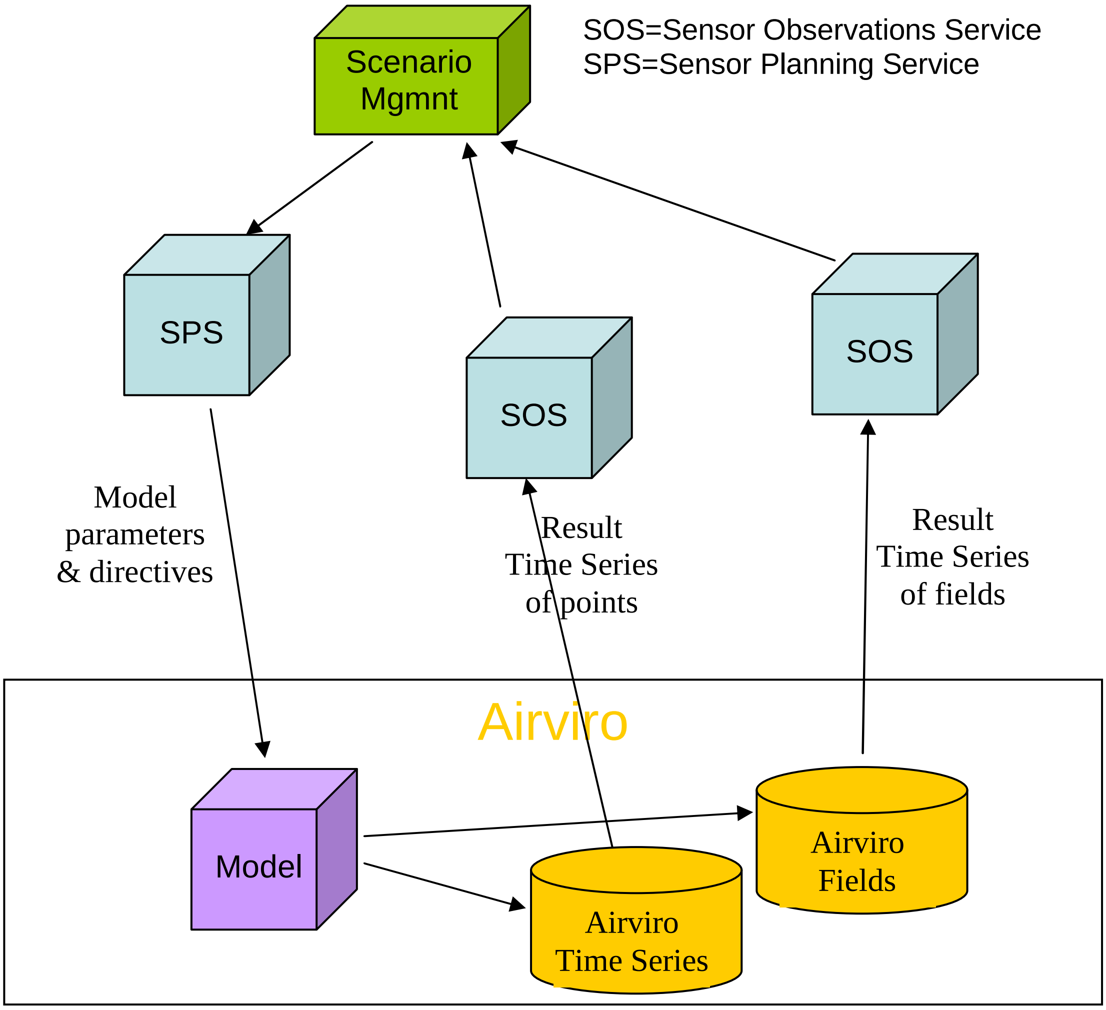
4.3 Intense rainfall on the urban scale: Design storm generator

The following list and figure indicates the services and data flows that are required to fulfil the CS use as specified in Section 3.1.2.

Services:

- Listing of Climate Scenarios.
- Model service for generating a design storm (static or dynamic).
  Input: rectangle, optionally locations for time series generation, max rain intensity (present climate), direction of passing storm, selected climate scenario.
  Output: Time series of precipitation for the storm duration either in selected locations or as a grid.

Data flow:



Technical solution for the back-back end

More details on the technical solution of the DSG (Design Storm Generator) implementation in the Common Services (back-back end) are found in Section 1.4 of Appendix 1.

4.4 Hydrological conditions: local downscaling

This section gives an overview of the hydrological downscaling service, to fulfil the CS use as specified in Section 3.2.3 Hydrological conditions: local downscaling.

Services:

- Listing of Climate Scenarios.
- Selection of the upstream area for local calibration
- Creating submodel of E-hype model for the local area
- Auto calibration of the local model based on local observation
- Running the new calibrated model to achieve future simulations

Data flow:

Figure 11 gives an overview of the different steps involved in the hydrological downscaling service. Based on the European scale E-Hype model, the user selects the relevant upstream area. After this he adds his observed data and re calibrate his model for this data. From this and pre calculated climate scenarios provided by SUDPLAN he receives results for his local area of interest which are calibrated to local observations. Physically, all these data are stored in the specialized time series repository.

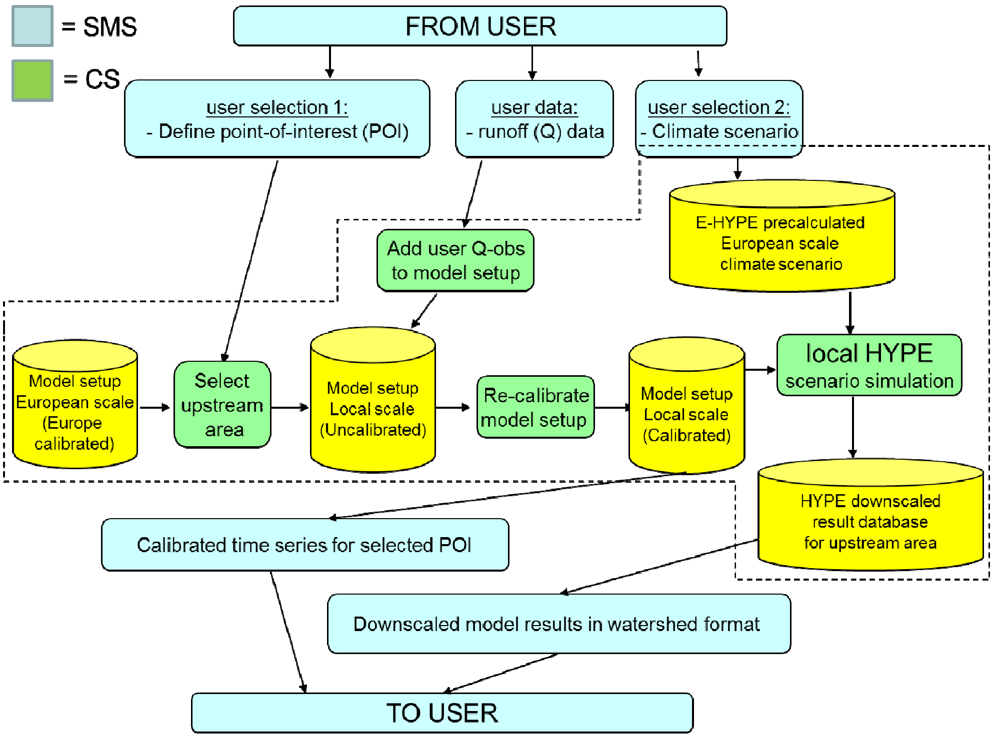


Figure 11 Components, databases and data flows for hydrological downscaling

Technical solution for the back-back end

More details on the technical solution of the hydrological downscaling implementation in the Common Services (back-back end) are found in Appendix 2.

4.5 Air quality: urban downscaling

The following list and figure indicates the services and data flows that are required to fulfil the CS use as outlined in Section 3.2.4 Air quality: urban downscaling.

List of Services required:

- Listing of Climate Scenarios.

- Model service for doing local downscaling with local emission data.
  This service is divided into: Upload input, Model, Access output.

  Input: Gridded emissions, yearly averages of NOx, NH3, PM, SO2, VOC and CO. Grid has yearly emission figures. Optionally also time variation (monthly, hourly)).
  Simulation area and grid size.

  Output: Model simulation results for different years (e.g. "present" 2009,2010, 2011, 2012 and "future" 2029, 2030, 2031, 2032 etc).

Data flow:

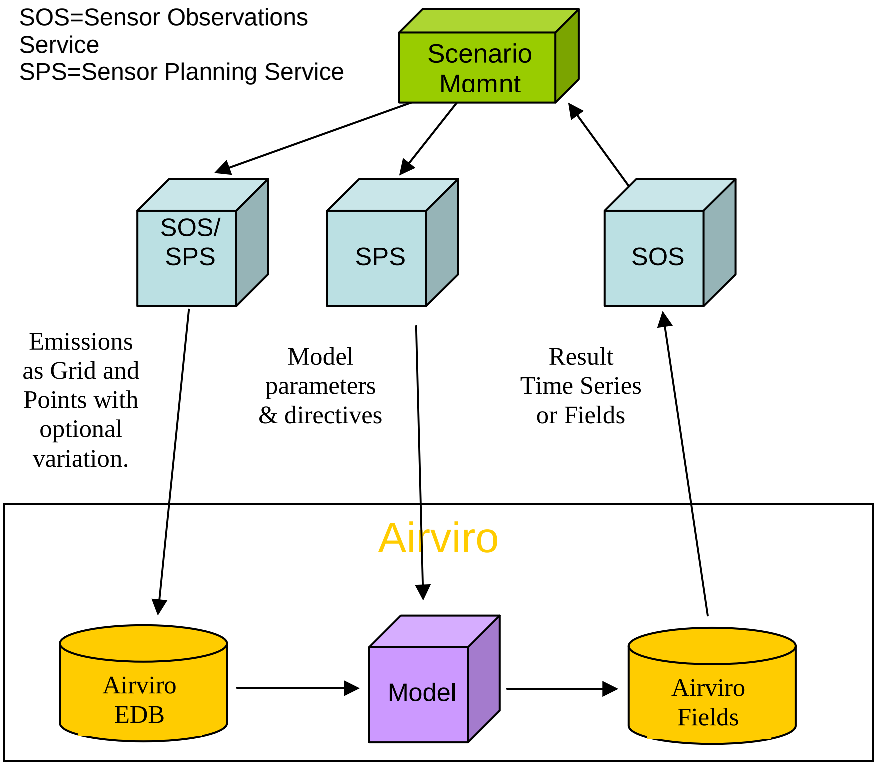


Figure 12 Components, databases and dataflows for air quality downscaling

Technical solution for the back-back end

More details on the technical solution of the AQ (Air Quality downscaling) implementation in the Common Services (back-back end) are found in Section 1.5 of Appendix 1.

5 Service layer for standardized communication

One of the key tasks in SUDPLAN is the integration of models with the Scenario Management System. This task encompasses two parts. The first part consists in the integration of the model as a piece of software itself while the second concerns integrating the model storage used as source for the model input data and destination for the model results.

The analysis of the Common Services and Pilot applications revealed several important conclusions and requirements directly influencing the integration of models, service topology and technology choice. The SUDPLAN models are heterogeneous, meaning that there will be a single instance of each model type running within the system sharing few commonalities with the other models. The models will most probably not run at the same site as the Scenario Management System. The model input data and their format is specific to a service instance. This is also true for the model results.

Minimizing the model integration overhead on the client side (SMS) can be done by using a Service Oriented Architecture (SOA) approach and the definition of generic interfaces for the models and model storage. This enables the implementation of generic (model independent) clients on the SMS side, avoiding the implementation of specific clients for each model. Instead of defining new proprietary service interfaces and information models for this purpose in SUDPLAN it has been decided to make use of existing standardised service interfaces to be able to blend in SISE seamlessly. These service interfaces emerged as results the work carried out by the Sensor Web Enablement (SWE) initiative of the Open Geospatial Consortium (OGC) and have been validated and extended within several European funded research projects like SANY[3] and OSIRIS[4]. The evaluated interfaces are described shortly in the following subsections followed by a short concluding section.

5.1 Sensor Observation Service (SOS)

The OGC Sensor Observation Service (OGC, SOS) provides a self-describing interface for accessing historical and real-time sensor observation data in a standardised way that is consistent for all sensor systems including remote, in-situ, fixed and mobile sensors. It makes use of the following information models and adjacent schemas: Observation and Measurement (OGC, O&M) information to model the returned sensor data and related meta-information and TransducerML (OGC, TML) and SensorML (OGC SensorML) description languages for modelling sensor related meta-information such as descriptions of sensors and sensor systems (Na and Priest, 2006).

[3] http://sany-ip.org
[4] www.osiris-fp6.eu

The Sensor Observation Service provides its functionality through the following interfaces and operations:

ServiceCapabilities Interface	SensorObservation Interface
getCapabilities	*describeSensor;* *getObservation;* *registerSensor;* *getObservationById;* *getResult;* *getFeatureOfInterest;* *getFeatureOfInterestTime* *describeFeatureType;* *describeObservationType;* *describeResultModel*

5.2 Web Processing Service (WPS)

WPS defines a standardized interface that facilitates the publishing of geospatial processes, and the discovery of and binding to those processes by clients. Processes include any algorithm, calculation or model that operates on spatially referenced data. A WPS can be configured to offer any sort of GIS functionality to clients across a network, including access to pre-programmed calculations and/or computation models that operate on spatially referenced data. A WPS may offer calculations as simple as subtracting one set of spatially referenced numbers from another (e.g., determining the difference in influenza cases between two different seasons), or as complicated as a global climate change model. The data required by the WPS can be delivered across a network, or available at the server. This interface specification provides mechanisms to identify the spatially referenced data required by the calculation, initiate the calculation, and manage the output from the calculation so that the client can access it. This Web Processing Service is targeted at processing both vector and raster data. The WPS specification is designed to allow a service provider to expose a web accessible process, such as polygon intersection, in a way that allows clients to input data and execute the process with no specialized knowledge of the underlying physical process interface or API. The WPS interface standardizes the way processes and their inputs/outputs are described, how a client can request the execution of a process, and how the output from a process is handled (Schut, 2007). The WPS Service provides its functionality through the following interfaces and operations:

ServiceCapabilities Interface	WPService Interface
getCapabilities	*DescribeProcess;* *Execute*

5.3 Sensor Planning Service (SPS)

The OGC Sensor Planning Service (SPS) defines an interface to task any form of sensor or model. Using SPS, sensors can be reprogrammed or calibrated, sensor missions can be started or changed, and simulation models can be executed and controlled. The feasibility of a tasking request can be checked and alternatives may be provided. SPS implementations cover a wide range of application scenarios. SPS is currently used to control assets such as simple web cams as well as satellite missions (Simonis, 2005). The SPS Service provides its functionality through the following interfaces and operations:

ServiceCapabilities Interface	SensorPlanning Interface
getCapabilities	*DescribeTasking* *GetFeasibilitiy* *Submit* *GetStatus* *Update* *Cancel* *DescribeResultAcces* *Reserve (v2.0)* *Confirm (v2.0)*

5.4 Web Coverage Service (WCS)

The OGC Web Coverage Service (WCS) provides a self-describing interface for discovery and query of geospatial data as coverages in a standardised way (digital geospatial information representing space-varying phenomena). WCS provides access to detailed and rich sets of geospatial information in a format suitable for client-side rendering and input into scientific models. It provides the coverage data together with detailed descriptions and query filtering capabilities against these descriptions (Whiteside and Evans, 2006).
The Web Coverage Service provides its functionality through the following interfaces and operations:

ServiceCapabilities Interface	Web Coverage Interface
getCapabilities	*describeCoverage* *getCoverage*

5.5 Web Map Service (WMS)

The OGC Web Map Service (WMS) produces maps of spatially referenced data dynamically from geographic information. This standard defines a “map” to be a portrayal of geographic information as a digital image file suitable for display on a computer screen. A map is not the data itself. WMS-produced maps are generally rendered in a pictorial format such as PNG, GIF or JPEG, or occasionally as vector-based graphical elements in Scalable Vector Graphics (SVG) or Web Computer Graphics Metafile (WebCGM) formats (de La Beaujardière, 2001). The WMS interface defines the following operations necessary to retrieve service level metadata, maps with well defined geographical and dimensional extents and information on particular features shown on map:

ServiceCapabilities Interface	Web Coverage Interface
getCapabilities	*GetMap* *GetFeatureInfo*

5.6 Web Feature Service (WFS)

The OGC Web Feature Service (WFS) interface encompasses operations for data access and manipulation operations on geographic features using HTTP as the distributed computing platform. Through this interface the client can combine, use and manage GML encoded geodata (the feature information behind a map image) from different sources. The OGC Geography Markup Language (GML) Implementation Specification (Vretanos, 2005) describes an encoding specification for geodata in XML that enables the storage, transport, processing, and transformation of geographic information. The WFS interface defines the following operations on geographic features and elements:

ServiceCapabilities Interface	Web Coverage Interface
getCapabilities	*DescribeFeatureType* *GetFeature* *GetGmlObject* *Transaction* *LockFeature*

5.7 Conclusion concerning OGC services

Two standardized service interfaces have been evaluated for the purpose of interfacing and controling the models in SUDPLAN, namely the Sensor Planning Service (SPS) and the Web Processing Service (WPS). Although exposing an apparently simpler interface the WPS lacks the necessary operations for managing the process runs. The SPS has the concept of tasks for managing the process (e.g. model) runs and the necessary operations for checking feasibility, getting status, cancelling or updating the tasks. For the above mentioned reasons it is recommended to use the SPS instead of the WPS interface.

There are several limitations that have to be dealt with when running models. The input datasets needed by models to run has to be stored at a location controlled by and easily accessible by the model usually called model storage. At the same time, because of its size, it is not feasible to provide these data as a parameter to the model run by value but instead a reference to the input data shall be used. An interface for providing (uploading) input datasets to the model storage is necessary. Also the model results are very large and need to be stored at a location controlled by and easily accessible (writable) by the model (model storage). Access to the results requires a generic interface in order to enable clients (SMS) to access results in a unified way and thus reducing implementation overhead. For these purposes two standardized web service interfaces for the model storage have been positively evaluated. Depending on the data type and organisation the Sensor Observation Service (SOS) and Web Coverage Service (WCS) shall be used. SOS shall be used mostly for time-series of simple values (non coverage type) and for discrete coverages in conjunction with a Web Feature Service (WFS). WCS shall be used for time series of discrete and continuous coverages. The transactional profiles of the SOS and WCS are the interface parts used to upload (write data) to the model storage.

Summarizing, SOS will be used to download and upload model and monitor results, while SPS will be used to run the models. WCS, WFS and WMS can be used where results (grid, polygons, layers) shall be presented over map. As priority for V1 version, we will focus on the upload and download of time series of precipitation (Linz-Wuppertal pilots) and download of air quality grids (Stockholm and Prague pilots).

5.8 Technical description of implemented OGC services

The documentation of the OGC services used for communication between the Scenario Management System and the Common Services can be found in

- Appendix 3: Common concepts used in all applications
- Appendix 4: Pan-European visualisation
- Appendix 5: Rainfall downscaling

All OGC documention will be given in the appendices of this public document. Although there are formally no more versions to come of the Common Services Concerted approach document, it will be updated during 2012 when all services are integrated and tested. So far Appendix 3-5 are available. The updated documents will be available on the SUDPLAN home page http://sudplan.eu/Results.

6 Conclusions and future activities

At the time of delivery of this report (m25), most of the Common Services functionalities have been implemented as back-back end services. Some parts are fully integrated with the SMS (Pan-European visualisation, Rainfall time series downscaling, Air Quality downscaling) while others are only working at command-line level (Rainfall IDF curve downscaling, Hydrological downscaling). Two items remain to be implemented at the back-back end level (Air Quality emission grid upload, Design storm generator), scheduled for early 2012.

The technical solutions for standardised (OGC) communication between the Scenario Management System (that includes SUDPLAN user interface) and the Common Services have been shortly described in this report, with details collected in five appendices, of which two are not (as of m25) completed because the related development work is ongoing. Also the technical solutions of the Common Services back-back end have been documented in two appendices, one for rainfall and air quality, the second for hydrology.

To date two climate scenarios have been made available. Further scenarios will be made available during 2012. A complete list of scenarios available by the end of the project cannot be made today as it depends on the progress of the climate modelling community during 2012, but the intention is to provide a large ensemble, spanning different global models, initial states and IPCC scenarios.

This report is the central document describing Common Services and will therefore be updated during 2012 and in particular in parallel with the Final Report (D.1.3.3). These updates will include aspects of the Common Services that are related to the remaining IT developments as well as for more environmental aspects (e.g. a complete list of available climate scenarios).

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8 Glossary

2D	Two-dimensional, typically a field that varies in east-west and north-south direction. The field may also vary in time –this is typical for e.g. air pollution and population density. The former varies from one hour to another while the latter maybe varies from one year to another.
3D	Three-dimensional, typically a field that varies in east-west and north-south direction as well as vertically. The field may also vary in time.
4D	Four-dimensional. Most often 3D field that explicitly also varies in time. It could also be when a certain 3D parameter (e.g. a particular air pollutant) also varies according to another 3D parameter (e.g. temperature). It will then be possible to study the variation of the first 3D parameter as a function of space (x,y,z) and the second parameter.
Airviro	Air quality management system consisting of databases, dispersion models and utilities to facilitate data collection, emission inventories etc, see http://www.Airviro.smhi.se/
Climate scenario	*Climate scenarios* means the resulting climate evolution over time, as simulated by global (GCMs) and regional (RCMs) climate models. Climate scenarios are products of certain emission scenarios that reflect different economic growth and emission mitigation agreements.
Common Services	*Common Services* is the climate downscaling services for rainfall, river flooding and air quality, developed in the SUDPLAN project and accessed through the SUDPLAN platform (Scenario Management System)
Common Services server	*Common Services* models will be executed at a SMHI server, accessible through OGC communication.
Emission scenario	These are of three types, of which the first one is behind the climate scenarios used in all SUDPLAN Common Services. The two remaining emission scenario types are only relevant for air quality downscaling.

- *IPCC emission scenarios*	*IPCC emission scenarios* are estimates of future global greenhouse gas concentrations based on assumptions about global development (economic growth, technical development, mitigation agreements, etc). During the first two years of the SUDPLAN projects, the climates scenarios based on SRES (Special Report on Emission Scenarios) A1B scenario from the 4th assessment have been used. The SRES emission scenarios do not include emissions of the pollutants of interest for air quality. If available the climate scenarios based on the 5th assessment RCP (Representative Concentration Pathways) emissions scenarios will also be used within the SUDPLAN project. They include emissions of air pollutants.
- *European tracer gas emissions (air pollutants)*	*European tracer gas emissions (air pollutants)* thus may or may not be included in IPCC emission scenarios. For creating Pan-European air quality fields under climate scenarios driven by the SRES A1B emission scenario, SUDPLAN uses tracer gas emissions from the more recent RCP emission scenarios. This inconsistency will be solved when climate scenarios based on RCP emission scenarios are available.
- *Local emission scenarios*	*Local emission scenarios* (to the atmosphere) are those of a particular European city. These will to a large extent influence future air quality in the city, but have little influence on global climate, nor do they influence air pollution concentrations in incoming long-range transported air. SUDPLAN will typically need gridded emissions with 1x1 km or finer spatial resolution as input to its urban air quality downscaling model.
Hind cast	A simulation of a historical period. Often done to compare model simulations with data which is available during that period.
Hot spot	Point (or small area) which is very different from its surroundings. In the present context, most often high concentrations of air pollutants, or extreme meteorological conditions.

Information product	Raw data, such as the results of mathematical modelling, and the analysis thereof, will often need to be packaged in such a way as to be accessible to the various stakeholders of an analysis. The medium can be one of a wide variety, such as print, photo, video, slides, or web pages. The term *information product* refers to such an entity.
Mockup	A model of a design used for demonstrating the functionality of a system.
Model	A *model* is a simplified representation of a system, usually intended to facilitate analysis of the system through manipulation of the model. In the SUDPLAN context the term can be used to refer to mathematical models of processes or spatial models of geographical entities.
PM_{10}	'PM10' shall mean particulate matter which passes through a size-selective inlet as defined in the reference method for the sampling and measurement of PM10, EN 12341, with a 50 % efficiency cut-off at 10 μm aerodynamic diameter;
$PM_{2.5}$	'PM2,5' shall mean particulate matter which passes through a size-selective inlet as defined in the reference method for the sampling and measurement of PM2,5, EN 14907, with a 50 % efficiency cut-off at 2,5 μm aerodynamic diameter;
Profile	Within SUDPLAN a *profile* is a set of configuration parameters which are associated with an individual or group, and which are remembered in order to facilitate repeated use of the system.
Regional downscaling	A climate scenario may be downscaled to a higher spatial resolution, typically 25-50 km, by a Regional Climate Model (RCM). The regional downscaling in SUDPLAN will be performed by SMHI's RCM (RCA, see below) and will generate climate scenarios at 44 or 22 km resolution.
Report	A *report* is a particular type of information product which is usually static and might integrate still images, static data representations, mathematical expressions, and narrative to communicate an analytical result to others.

Scenario	A *scenario* is a set of parameters, variables and other conditions which represent a hypothetical situation, and which can be analysed through the use of models in order to produce hypothetical outcomes. In SUDPLAN a scenario is an individual model simulation outcome to be used in urban planning. The model simulation may or may not include Common Services downscaling (with specific input) and may or may not include a local model simulation (with specific input and parameters).
Scenario Management System	*Scenario Management System* is synonymous with SUDPLAN platform
Scenario Management System Framework	The *Scenario Management System Framework* is the main Building Block of the Scenario Management System. It provides the Scenario Management System core functionalities and integration support for the other Building Blocks.
Scenario Management System Building Block	Scenario Management System Framework is composed of three distinct *Building Blocks*: The Scenario Management System Framework, the Model as a Service Building Block and the Advanced Visualisation Building Block.
Street canyon	Volume between high buildings in cities. Due to poor circulation (and high emissions) prone to poor air quality. Street canyons have unexpected circulation patterns, thus dedicated models are needed to study air pollution here.
SUDPLAN application	A *SUDPLAN application* is a decision support system crafted by using the SUDPLAN platform and integrating models, data, sensors, and other services to meet the requirements of the particular application.
SUDPLAN platform	The *SUDPLAN platform* is an ensemble of software components which support the development of SUDPLAN applications.
SUDPLAN system	*SUDPLAN system* is synonymous with SUDPLAN application

Urban downscaling	This refers to further downscaling of the regional climate scenarios for Europe to the urban scale within SUDPLAN. This will be possible for a) *rainfall/precipitation* where the temporal resolution will be 30 minutes or less. The spatial resolution will be that of a precipitation gauge, i.e. representative for a point rather than a certain area. b) *hydrological variables (river runoff, soil moisture etc*) where the temporal resolution is daily and the spatial resolution linked to catchment areas which presently count approximately 35000 and with average size 240 km^2. *c) air quality (PM, NO2/NOx, SO2, O3, CO).* The temporal resolution will be hourly for gridded output fields and the spatial resolution typically 1x1 kilometres.
User	The term *user* refers to people who have a more or less direct involvement with a system. Primary users are directly and frequently involved, while secondary users may interact with the system only occasionally or through an intermediary. Tertiary users may not interact with the system but have a direct interest in the performance of the system.
Web-based	Computer applications are said to be *web-based* if they rely on or take advantage of data and/or services which are accessible via the World Wide Web using the Internet.

9 Acronyms and Abbreviations

Acronym	Description
A1B	Emission scenario used for global climate modelling in IPCCs Fourth Assessment Report (AR4)
Airviro	Air quality management system to facilitate data collection, emission inventories etc, see http://www.airviro.smhi.se/
CS	Common Services
AVDB	Airviro Time Series database (used for storage in Common Services)
AR4, AR5	Fourth and Fifth Assessment Report of IPCC
AQ	Air Quality
C API	Application Programming Interface written in C
CMIP5	Coupled Model Intercomparison Project, phase 5 (coordinated model exercise in support to AR5)
CS	Common Services (SUDPLAN functionality)
CTM	Chemistry Transport Model
CTREE	FairCom CTREE database (Index database, core of AVDB)
DBS	Distribution-Based Scaling, a method to bias-correct (i.e. remove systematic errors in) the temperature and precipitation of the RCM output
DoW	SUDPLAN Description of Work
DSS	Decision Support Systems
ECHAM5	GCM developed at Max Planck Institute for Meteorology, DE
ECMWF	The European Centre for Medium-Range Weather Forecasts (also co-ordinating FP7-SPACE project MACC)
EDB	Airviro Emission database
EEA	European Economic Association
E-HYPE	HYdrological Predictions for the Environment (European set-up), hydrological rainfall-runoff model developed and used by SMHI
EM&S	Environmental Modelling and Software
ESA	European Space Agency
ESDI	European Spatial Data Infrastructure
EU	European Union
GCM	Global Climate Model or, equivalently, General Circulation Model. Physically based computer model that simulates the global climate on a 200-300 km resolution. Can be used both to reproduce historical climate and estimate future climate, e.g. in response to changes in greenhouse gas concentrations.
GHG	GreenHouse Gases
GTE	Georeferenced Time-series Editor
GIS	Geographic Information System
HadCM3	GCM developed at Met Office Hadley Centre, UK

HIRLAM	HIgh Resolution Limited Area Model, numerical weather prediction model developed and used operationally by SMHI
ICT	Information and Communication Technologies
ID	Identifier
IDF-curve	Intensity Duration Frequency-curve, a curve (or a table of values) showing the rainfall intensity associated with a certain duration (i.e. time period) and frequency (i.e. probability, generally expressed as a return period). Calculated from short-term rainfall observations and widely used in design of urban drainage systems.
iEMSs	International Environmental Modelling & Software Society
IFIP	International Federation for Information Processing
IPCC	The Intergovernmental Panel on Climate Change, the leading body for the assessment of climate change
IPR	Intellectual Property Rights
ISAM	Indexed Sequential Access Method, a method for indexing data for fast retrieval
ISO	International Standardization Organisation
ISESS	International Symposium on Environmental Software Systems
IST	Information Society Technology
MATCH	Multiple-scale Atmospheric Transport and Chemistry modelling system, a CTM developed and used by SMHI.
MODSIM	International Congress on Modelling and Simulation
OASIS	1) Organization for the Advancement of Structured Information Standards 2) Open Advanced System for Disaster and Emergency Management (FP6 project)
OGC	Open Geospatial Consortium
O&M	Observation and Measurements
ORCHESTRA	Open Architecture and Spatial Data Infrastructure in Europe (FP6 IST-511678)
OSGeo	Open Source Geospatial Foundation
OSIRIS	Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors (FP6 IST-33799)
PMC	Project Management Committee
RC	Rossby Centre, climate research unit at SMHI
RCA	Rossby Centre Atmospheric model, RCM developed by SMHI and used in SUDPLAN
RCM	Regional Climate Model, commonly used to increase the spatial resolution of climate scenarios to 25-50 km in a specific region.
RCP4.5	Radiative Concentration Pathways: A set of four emission scenarios to be used for the AR5 simulations. The scenarios are named according to their radiative forcing at 2100, e.g. 4.5 W/m^2.
RNB	Airviro Field database
SANY	Sensors Anywhere (FP6 IST-033654)
SDI	Spatial Data Infrastructure

SISE	Single Information Space in Europe for the Environment
SISE	Single Information Space in Europe for the Environment
SMHI	Swedish Meteorological and Hydrological Institute
SMS	Scenario Management System
SOA	Service Oriented Architecture
SOS	Sensor Observation Service
SPS	Sensor Planning Service
SWE	Sensor Web Enablement
SUDPLAN	Sustainable Urban Development PLANner for climate change adaptation
SWE	Sensor Web Enablement
Tbd	To be determined
UWEDAT	AIT environmental data management and monitoring system
WCC	World Computer Congress
WCS	Web Coverage Service
WFS	Web Feature Service
WP	Work Package
WPS	Web Processing Service
WMS	Web Map Service