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1. Management summary

The SUDPLAN project develops a planning, decision support and training tool to assess 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, river flooding and air quality; accessible on the web through the Scenario Management System. The downscaling simulation results are improved by local input from the end user, i.e. Common Services can be described as interactive climate services.

The following downscaling functionality is implemented in Common Services:

- Intense rainfall: urban downscaling – generation of short-term precipitation data for urban hydrological climate change impact assessment

- Intense rainfall: storm water generator – generation of data for design and performance assessment of urban hydrological systems, including climate change

- Hydrological conditions: urban downscaling – local calibration of hydrological variables and generation of future runoff scenarios

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

This report documents the air quality downscaling services, with a focus on the description of end user functionality, as a complement to the software itself. Some experiences gained during the experimentation of air quality downscaling are given. More IT related documentation can be found in the appendices of D4.1.2 Concerted Approach V2.

The air quality downscaling in the Common Services V2 is now (m25) fully operational, although through the Airviro user interface and not through the SUDPLAN SMS user interface. Future air quality projections have been made for both Stockholm and Prague, of direct interest for those two pilots and external stakeholders linked to SULVF and CENIA.

The preparation of detailed emission inventories that reflect local urban planning, for present and future years, may require large efforts even for well-experienced users, as exemplified by the Stockholm pilot. A possible way to initiate the generation of emission scenarios for future years is to use GAINS model emission scenarios for the country/region of interest.

The air quality downscaling is computationally expensive and a modified procedure has been introduced to reduce calculation times.

The use of the SUDPLAN platform to manage air quality downscaling is presented by the two pilots, WP5 (Stockholm) and WP8 (Czech Republic), see e.g. their pilot V2 reports D5.2.2 and D8.2.2, respectively.

For 2012 the upload of emission grids will be implemented as part of the Common Services back-back end services.

This is a public document available at http://www.sudplan.eu/results.

2. Air Quality: Urban downscaling

The Air Quality (AQ) downscaling is performed by running the CS CTM[1] model over a specific city, using existing Europe scale model results for forcing and boundary conditions – a procedure also known as off-line nesting. This will yield a model result for part of the period of the Europe scale simulations, but with a much higher spatial resolution over the specific city (see Figure 1 example). The downscaling requires input of local emission with high spatial resolution, if the downscaling shall be meaningful.
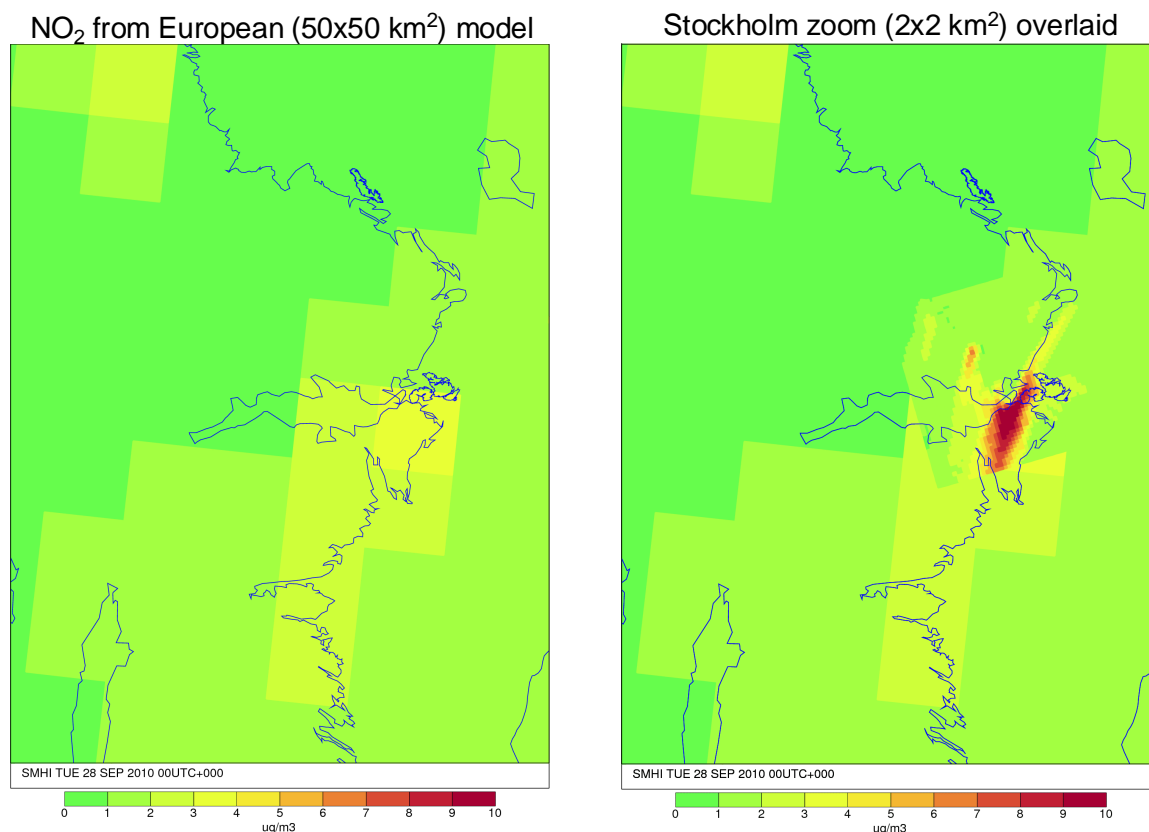

Figure 1 Example showing how the downscaling improves the level of detail of the simulated air pollution

Common Services (CS) provides the climate and environmental information to end user through the Scenario Management System (SMS), which is a model control, visualisation and integration workbench for all SUDPLAN components (Figure 2). A standardized communication will assure an easy setup connection to the Common Services, also for other software which require climate services of this type.

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

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[1] Chemistry Transport Model

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.

Figure 2 Overview of SUDPLAN components. The communication between Common Services and the Scenario Management System uses standardized services (OGC).
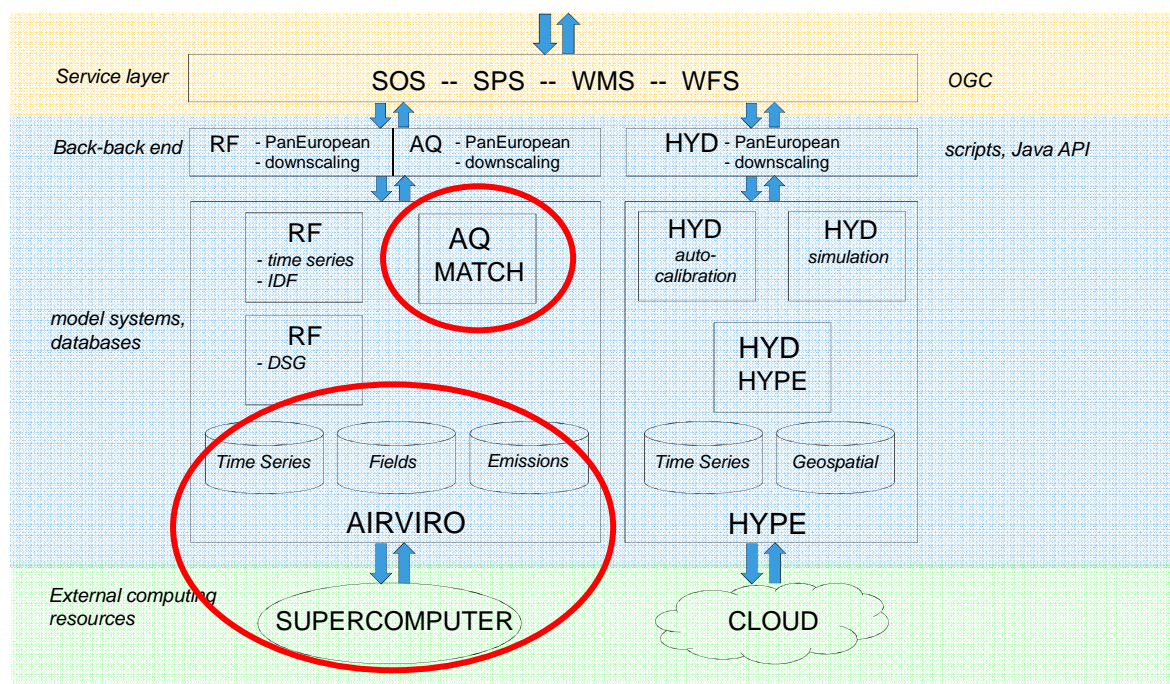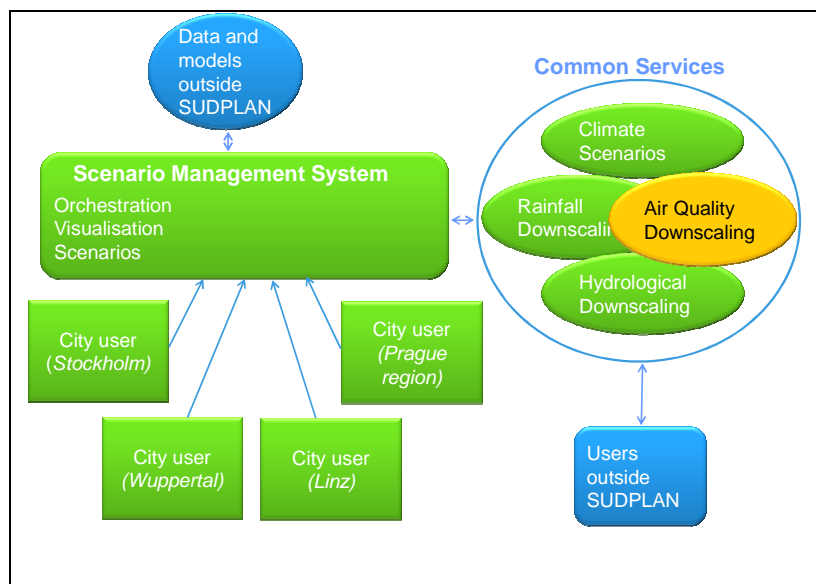

Figure 3 Technical solution of Common Services, with air quality downscaling components marked.

The air quality downscaling components (marked in Figure 3) forms part of the Airviro model system, which also supports the rainfall downscaling. This document describes how the downscaling is performed in SUDPLAN. Technical descriptions concerning the dispersion model MATCH and other components of the air quality part of Common Services environment is found in D4.1.2 Common Services concerted approach V2. The D4.1.2 document includes

appendices documenting the OGC communication[2] and also an appendix which documents the technical solution of the back-back end, i.e. how scripts can be used to communicate with the Common Services, select model, model domain and parameters, input data (emissions, forcing, boundary conditions), proceed to execution and then to access output. The description given in the present document focuses more the user functionality, leaving the specific IT solutions for the D4.1.2 document.

The full use of the SUDPLAN platform to manage AQ downscaling will be presented by WP5 (Stockholm) and WP8 (CENIA).

2.1. Downscaling procedure

The green parts of Fig. 2 show the principles for the air quality downscaling. Two types of user input are needed to launch a model simulation:

1. CS receives from SMS the coordinates for the rectangle defined as downscaling area, together with some identification of the coordinate system and map projection[3]. The user has to specify which European scale air quality result - based either on a future climate scenario or on a historical period (hindcast) - to use as boundary conditions for the downscaling, this from a list of available European model results (Figure 4). Finally the user has to specify the simulation period (first and last day of a period that must be included in the selected European scale air quality result. The maximum length is one calendar year.
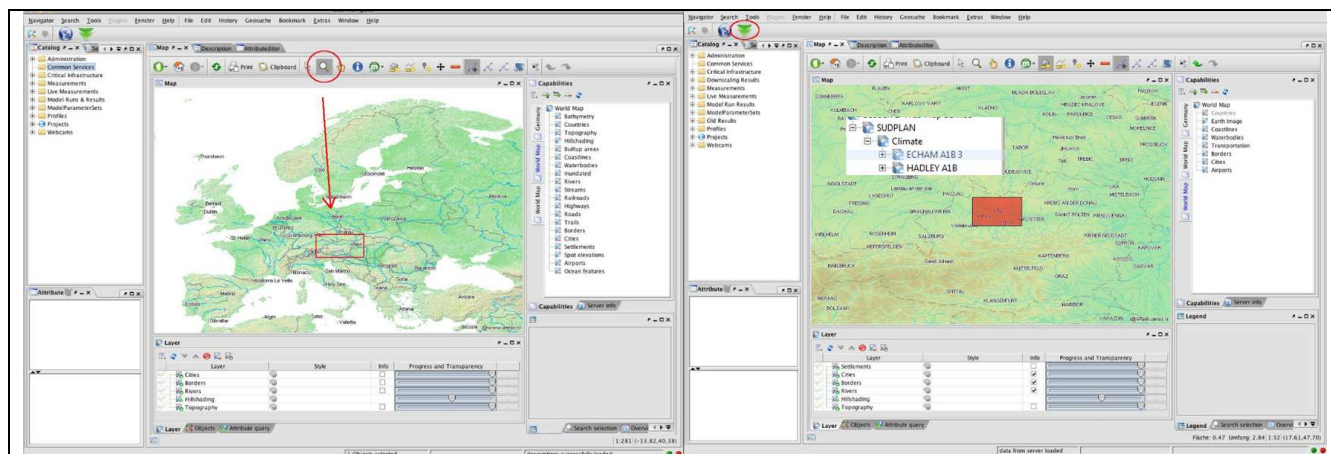

Figure 4. SMS user interface for air quality downscaling (mockup): Zooming into the map (left) and selecting area for air quality downscaling (right).

2. Emission data for the downscaling area, with high spatial resolution, should be stored in the CS Airviro database prior to model simulation. In V2 it will be assumed that the user has prepared the database through the standard Airviro web interface. Note that there will be only one emission database for the entire downscaling period.

   The final version will accept SMS uploads of emission grids, creating new Airviro

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[2] Note that the air quality specific part of the OGC documentation is still (m24) not completed, however the D4.1.2 document will be updated under 2012.

[3] For the European scale WGS84 is default, however end users may use their standard projections for their city.

databases. There will also be tables to specify seasonal (monthly) and daily variations in the emissions (e.g. depending on variations in traffic volume).

Air quality models require a temporal resolution (hours) because urban emissions are very different during the hours of the day. Moreover emissions are likely to vary between working days and weekend, as well as between different seasons of the year. This can be solved by sending hourly emission grids from the Airviro database to the supercomputer where the model is executed. End users will be able to upload emission (more precisely activity pattern) tables from the SMS user interface to the Common Services/Airviro database.

3. As there likely exists a year-to-year variability due to meteorology, the typical procedure for air quality downscaling will be to first create multiple 1-year simulations representing "present" conditions, e.g. 2009-2010-2011 (they can all use the same emission database, since emissions will not have a strong year-to-year variation). Then a "future" time window of similar length is chosen, e.g. 2029-2030-2031, for which the model is executed three times. The time windows can be chosen within the limits of the Pan-European results, which for the two present scenarios is 1960-2100.

4. Model output stored at CS server, accessible through SMS (Figure 5). The air quality downscaling in Common Services will output gridded concentrations of NO2, NOx, O3, SO2 and PM10 with hourly, daily, monthly and annual temporal resolution (seen in the SMS result list as four different results). The annual result file will only consist of one field, the annual average for that particular year. However, the hourly result file will include around 8760 hourly average gridded results.

The requirements for visualisation and further result processing have been defined by the Stockholm and Czech pilots, see their pilot definition plans V2 (D5.1.2 and D8.1.2). Common Services allow 2D visualisation of the concentration fields with colour settings defined by the user. For specific locations a time series graph can be displayed. Individual grids (i.e. the one displayed over the map) can be exported to some standard format (e.g. EXCEL). Also visualised time series may be exported e.g. in EXCEL or CSV format.
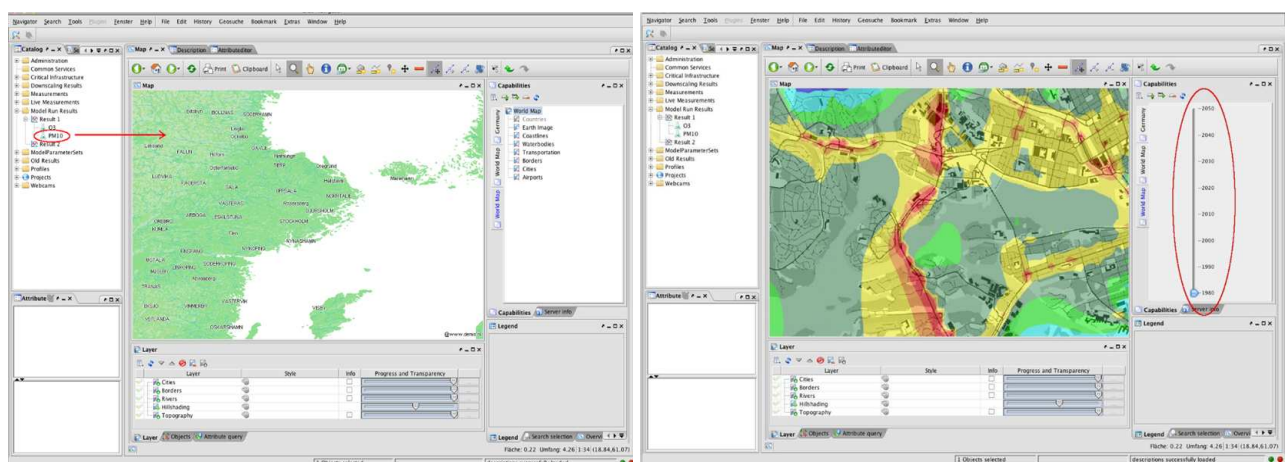

Figure 5. SMS user interface for air quality visualisation (mockup): Dragging downscaling result file into map (left) and 2D visualisation of air pollutant concentration (right).

2.2. Use of air quality downscaling results

Figure 6 gives an example of how the air quality downscaling can be used to project what will happen with NO2 levels in Stockholm up to 2030, taking into account various changes:

- Climate change
- Changed emissions over Europe
- Changed emissions in Stockholm (better vehicle technology, more traffic, new transit road etc).

More details on this type of application can be found in the Stockholm pilot report V2 (D5.2.2) and the Czech pilot report V2 (D8.2.2).
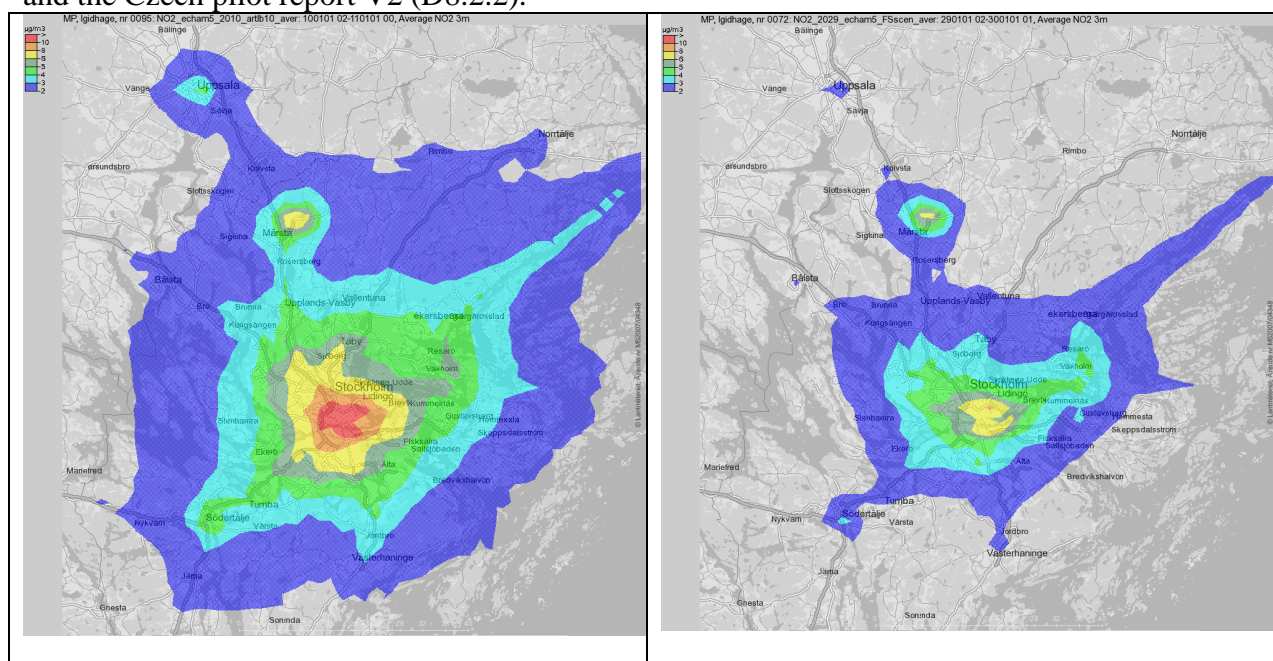

Figure 6. Annual average values for urban background concentrations of nitrogen dioxide: Year 2010 with present local emissions (left) and year 2029 with future emissions and new transit road (right), both using ECHAM5 A1B climate and RCP4.5 emission scenario for Europe (visualisations taken from Airviro user interface).

2.3.   Overview of components and data flows

Figure 7 illustrates the components and data flows involved in the air quality downscaling procedure. More details found in D4.1.2 Concerted Approach V2.
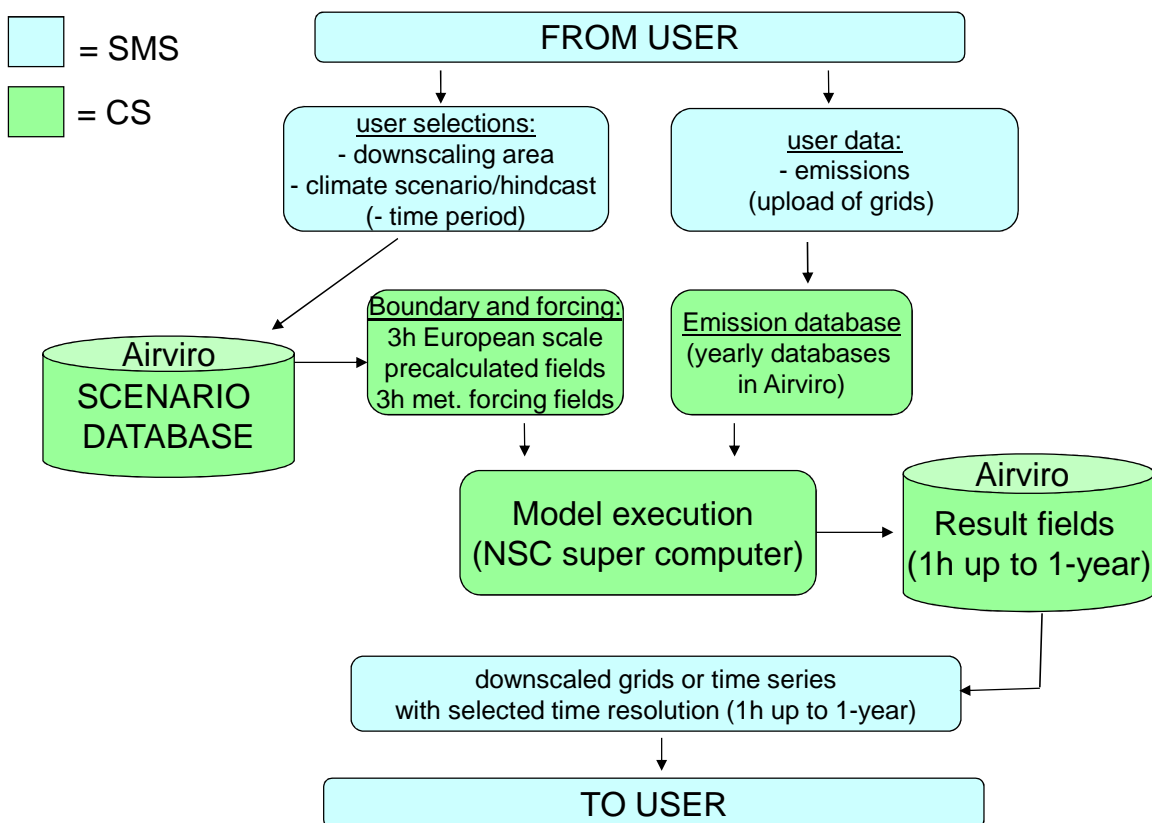

Figure 7. Components and data flows between SMS and CS for air quality downscaling.

The AQ downscaling performed and visualised in this document has been administrated through the Airviro web user interface.

2.4.   Experiences gained during experimentation

The back-back end functionality of the Common Services air quality downscaling has been extensively used by both WP5 (Stockholm) and WP8 (Czech Republic) partners. This has been possible through the use of the Airviro web user interface, which permits model execution and result analysis in a similar way as the SMS user interface. The air quality downscaling is the computationally most demanding application of the Common Services and it requires also huge amounts of input data. Here are some experiences from the WP5 and WP8 experimentation:

1. If emission databases of required quality (e.g. concerning spatial and temporal variability) are not available, a rather large preparatory effort is needed in order to be able to perform useful air quality downscaling simulations. For Stockholm a database describing present conditions was available from project start, but the built up of a future emission database of interest (for assessment of a planned transit road through Stockholm) was time

consuming. This is partly due to the level o detail of the Stockholm database, which means that the entire road network – also new road links - are described as individual emission line sources. For the Czech pilot, which involved the built up by databases both for present and future conditions, we used a simpler approach so that the spatial distribution of emission sources were based on grids with identical spatial distribution for present and future databases. The difference was in the emission amplitude for different sectors, e.g. road traffic, large point source (energy, heavy industry) etc. The projected evolution of the those emissions were taken from a GAINS model scenario, an efficient and well documented way to create, in a top-down way[4], future emission scenarios. The importance of well defined and documented emission scenarios is fundamental for discussing the validity of the air quality downscaling results.

2. The physical calculation times are huge. The first reason is the preparation of emission input data. We found that the search of hourly emission grids, performed within the Airviro server at SMHI, could easily take 1-2 days for one year simulation. SUDPLAN should benefit from a faster search here, a development in this respect is planned for the coming year. The second reason of long calculation times is the true CPU needed on the supercomputer system for the photochemical model simulation (MATCH model). SUDPLAN is currently working on 4 nodes, possibly this can be extended in the future. The spatial resolution (the total number of cells in the grid domain) is highly influencing calculation times. While a 2x2 km grid over the Stockholm domain (the one shown in Fig. 3) takes about one day for a year period, the completion of a 1x1 km grid will increase 4 times (to 4 days). Obviously the end user has to consider the need of spatial resolution and balance it with the need of doing multiple executions (e.g. with different years and with different climate scenarios as input).

   The long calculation times has forced the project to a revised procedure for air quality downscaling simulations. Instead of running continuously for the same period as the climate scenario used as forcing – presently 140 years - a revised procedure has been developed. The simulations are all made for one calendar year, but grouped three or five years together in "time windows". Example: presentation conditions given by 2009-2010-2011 and future conditions by 2029-2030-2031. Note that it is important to have various years in the window, since there may be significant year-to-year variability in meteorological conditions. Emissions normally do not fluctuate between one year and another, so it will be enough with one emission database for each time window.

3. The storage of Pan-European air quality results is highly demanding in disk space, since the 140 year simulations (of which we now have two scenarios based on different GCMs) must have all level data stored over the entire Europe and with a temporal resolution of at least 6 or better 3 hours. We found out that all this data can not be stored on the Airviro server at SMHI, instead they are stored on disc at the supercomputer centre. Only daily average data for the lowest (ground) level and for a few of all chemical species handled by the MATCH model, have been transferred to the Airviro server and are available for the PE visualisation of time series.

4. End user reactions on the results so far are promising. We can see that actions taken to reduce pollution emissions will be the most important factor for future air pollution levels

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[4] Top down means that a global change of emissions are applied identically over a given spatial distribution, the latter e.g. created by the distribution of known "activities" such as population density and traffic volume.

in European cities. We have so far seen that the climate change effect on e.g. ozone levels is typically smaller than the effect of expected reductions of precursor emissions. For some pollutants like NO2, local action in each city will be decisive if compliance with EU directive will be achieved.

3.   Conclusions

The air quality downscaling in the Common Services V2 is now (m25) fully operational, although pilot work during 2011 has been performed through the Airviro user interface and not through the SUDPLAN SMS user interface. Future air quality projections have been made for both Stockholm and Prague, of direct interest for those two pilots and external stakeholders linked to SULVF and CENIA.

The preparation of detailed emission inventories that reflect local urban planning, for present and future years, may require large efforts even for well-experienced users, as exemplified by the Stockholm pilot. A possible way to initiate the generation of emission scenarios for future years is to use GAINS model emission scenarios for the country/region of interest.

The air quality downscaling is computationally expensive and the downscaling procedure has been modified to reduce calculation times.

For 2012 the upload of emission grids will be implemented as part of the Common Services back-back end services.

4.   References

D4.1.2 Common Services concerted approach V2.pdf

D5.1.2 Stockholm Pilot Definition Plan V2.pdf

D8.1.2 Czech Pilot Definition Plan V2.pdf

D5.2.2 Stockholm Pilot report V2.pdf

D8.2.2 Czech Pilot report V2.pdf

5. 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.

6. 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	Organization for the Advancement of Structured Information Standards 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