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1. Management summary

SUDPLAN Common Services represent a common functionality to be used by the four SUDPLAN pilot cities. The functionality is general and can in the future be extended to be used in all European cities. The Common Services (CS) offers urban downscaling services for intense rainfall, hydrological variables (including flooding, droughts and water availability) and air quality; accessible on the web through the Scenario Management System (SMS).

The following downscaling functionality is implemented in Common Services:

- Intense rainfall: urban downscaling – generation of short-term precipitation data (time series or IDF curves) 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

COVERED IN THIS REPORT

- Hydrological conditions: downscaling of upstream catchment area – 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 rainfall downscaling services, with a focus on the description of end user functionality, as a complement to the software itself. More IT related documentation can be found in the appendices of D4.1.2 Common Services Concerted Approach V2.

The urban rainfall downscaling in the Common Services V2 is now (m24) operational. The use of the SUDPLAN platform to manage rainfall downscaling is presented by the two pilots, WP6 (Wuppertal) and WP7 (Linz), see e.g. their pilot V2 reports D6.2.2 and D7.2.2, respectively. Future rainfall projections have been made for both Wuppertal and Linz, of direct interest for those two pilots and associated external stakeholders. In Linz the downscaled rainfall data have been used in sewer modelling and assessment of future combined sewer overflow rates.

The Common Services design storm generator has been implemented and tested, integration with the Scenario Management System and its user interface will take place in V3. Further, the time series downscaling is to be upgraded with support for rainfall frequency adjustment.

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

2. Introduction

This report documents the rainfall downscaling services, as a complement to the software itself. The selected method for rainfall downscaling, the Delta Change method, is described and motivated in Section 3. The downscaling service, with two types of possible input (time series, IDF-tables) is described in Section 4. An overview of the technical solutions can be found in Section 5, while more detailed IT descriptions can be found in a separate document D4.1.2 Common Services Concerted Approach V2. The additional service of a design storm generator, to be integrated in Common Services during 2012 (V3), is described in Section 6. Some general experiences gained during the experimentation with rainfall downscaling are given in this report, but discussions around specific rainfall downscaling results can be found in the Wuppertal and Linz pilot reports.

3. Rainfall downscaling by Delta Change

For urban hydrological applications and climate change impact assessment, rainfall data from climate models need to be downscaled as the scales of Regional Climate Models (RCMs) differ from the scales of urban hydrological models. The latter typically work with a temporal resolution of a few minutes and a spatial resolution of a few km² (i.e., the typical size of an urban catchment; in practice rainfall data from a single gauge - i.e. a point value - is typically used). Concerning the temporal scale, the internal time step of RCMs is typically 15-30 min which is close to the urban scale. Often, however, output is not saved on this high resolution but maybe as 3-hr and 6-hr values. Concerning the spatial scale, the grid size of RCMs is typically 25×25 km (625 km²) or 50×50 km (2500 km²) which is far more coarse than the urban scale. Rainfall intensities averaged over 1000-2000 km² are fundamentally different from point observations, having higher rainfall frequency and much lower extreme values. Therefore raw RCM rainfall output cannot be used in urban hydrological applications, a downscaling is needed.

There are different ways to perform (spatial) rainfall downscaling. One common way is to adjust the RCM rainfall based on local observations in a historical control period (bias correction). Another common way does not use the RCM rainfall but is based on statistical relationships between large-scale atmospheric circulation variables (e.g. pressure and wind) from the RCM and local rainfall. A lot of work has verified the performance of these approaches on time scales of 1 day or longer, but for shorter time scales their applicability is limited. This is mainly because the statistical properties of local rainfall (extremes) strongly diverge from the properties of grid-scale rainfall when the time scale decreases. Also the strength of relations between large-scale variables and local rainfall decreases for small time scales. Finally, the amount of sub-daily rainfall observations is far smaller than the amount of daily observations, which makes sub-daily adjustment and regression much more uncertain.

In light of these limitations of these established techniques, another option - the Delta Change (DC) approach - has been selected in SUDPLAN. In DC, no attempt to match RCM rainfall with observations is made. Instead the RCM rainfall is analysed only with respect to future changes. Thus, some key property of rainfall (e.g. average annual rainfall) is calculated both for a long period representing today's climate (often 1961-1990, traditionally) and an equally long period representing future climate (e.g. 2071-2100). The resulting relative change (e.g. 15% increase) is then transferred onto an observed time series, e.g. by multiplying all values by 1.15. By this strategy, downscaling is achieved in the sense that the local nature of the observations is preserved, but with a modification that reflects some key aspect of the expected future change as given by the RCM.

DC was widely used in early hydrological climate change impact assessments and is still a main method, besides the ones mentioned above. Since the early applications, more elaborate ways to apply the procedure than only for average annual rainfall have been developed, e.g. by considering changes associated with different rainfall intensity levels. In SUDPLAN, further development has been made (see section 3 below).

It must be emphasized that DC has its limitations, the main limit is the required assumption that changes in the rainfall properties calculated at the RCM grid scale are also valid for the local scale. This is not certain, as different rainfall mechanisms have different weight regarding the different scales. For example, local rainfall extremes are generally produced by convective rainfall cells whereas grid-scale extremes may also be related to larger-scale, frontal-type rainfall systems. While the qualitative impact of global warming is likely similar in both cases, the rate

of change is not necessarily the same. Some studies indicate a somewhat higher future increase of rainfall intensity on the local as compared to the grid scale. This indicates that the grid-scale changes may be seen as a conservative estimate of the local changes.

Despite the limitations, DC is conceivably the most robust approach to include in the SUDPLAN Common Services. Modification of local time series has the significant advantages that results (from e.g. an urban sewer model) obtained using the downscaled (i.e. Delta Changed) data may be directly compared with existing results from the historical data. As historical data are used in local models already, the downscaled data are directly applicable in the local models without another processing step This is not the case in alternative downscaling approaches, which would generate downscaled data also for the historical period, i.e. simulated data that differ from the historical observations. Then impact assessment would require an additional step of evaluating the ability of the RCM to reproduce today's climate and the associated additional uncertainty.

4. Rainfall downscaling services in SUDPLAN

In the final version of Common Services, two types of urban downscaling of intense rainfall will be available, for (1) continuous short-term rainfall time series and (2) Intensity-Duration-Frequency (IDF) curves (i.e. extreme value statistics). This document describes the concepts used and how the downscaling is performed inside the CS model system. Technical descriptions concerning the Delta Change method and other components of the intense rainfall part of CS environment can be found in D4.1.2 Common Services concerted approach V2. The D4.1.2 document includes appendices documenting the network communication layer (OGC communication[1]) 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 native model systems, select model, model domain and parameters, input data (time series, IDF curves), proceed to execution and then to access output. The description given in the present document focuses on the user functionality, leaving the functional specification at service level as well as implementation details to the D4.1.2 document. The urban rainfall downscaling mechanisms in the Common Services V2 are now (m25) fully operational.

The two types of downscaling services, time series and IDF curves, involve a common general chain of steps.

- Historical, observed data representing a specific location are uploaded and location coordinates specified (e.g. precipitation station).
- Two 30-year periods are specified, one representing the historical observations and one representing the desired future period to investigate, and a climate scenario is selected.
- For each selected 30-year period, 30-min RCM precipitation time series from five grid boxes surrounding the location are retrieved.
- The RCM data are statistically analysed.

[1] Note that the rainfall specific part of the final OGC service related documentation is still (m24) not completed, however the D4.1.2 document will be updated during 2012.

- The estimated future changes are projected onto the observed data (this is the downscaling).
- The (observed and) downscaled is offered to be visualised and downloaded.

In the following, the downscaling services are described in more detail.

4.1. Continuous case: time series downscaling

In this application, the DC method is implemented to transfer future changes of the probability distribution of 30-min rainfall intensities to short-term rainfall observations. The method is based on a frequency analysis of non-zero 30-min rainfall in RCM output. Based on the analysis, non-zero registrations in an observed series are modified to represent the future distribution (see D4.1.2 for further details). In the current version (V2) no change in the frequency of rainfall occurrence (wet/dry periods) is made, but support for this will be implemented in V3 (see below).

The input is a historical time series of short-term rainfall, from e.g. a tipping-bucket gauge. The mid-point of the observed time series defines the centre of the 30-year reference period. The main output is a time series which differs from the uploaded one in two ways (Figure 1).

1. In each time stamp, the observation year has been replaced by a future target year.
2. Each rainfall registration has been re-scaled to account for future changes in the probability distribution of short-term rainfall intensities.

The automated CS downscaling functionality has been developed and verified using short-term rainfall data from Kalmar, Sweden, that are well known to the developer and thus optimal for this purpose. Figure 2 shows the first part of the original and the downscaled time series. In this data, the gauge resolution was 0.2 mm; thus all original observations have this value. In the downscaling procedure, the gauge resolution is assumed to be variable and modified to account for the climate change impact. In this application, a target period 70 years ahead was used, which is reflected in the time stamps (Figure 1).

ORIGINAL TIME SERIES		DOWNSCALED TIME SERIES	
1991-10-01 19:04	0,2	2061-10-01 19:04	0,20666
1991-10-01 19:11	0,2	2061-10-01 19:11	0,20666
1991-10-01 19:15	0,2	2061-10-01 19:15	0,20666
1991-10-01 19:30	0,2	2061-10-01 19:30	0,19427
1991-10-01 19:39	0,2	2061-10-01 19:39	0,19427
1991-10-01 21:04	0,2	2061-10-01 21:04	0,19427
1991-10-02 14:17	0,2	2061-10-02 14:17	0,20594
1991-10-02 14:18	0,2	2061-10-02 14:18	0,20594
1991-10-02 14:18	0,2	2061-10-02 14:18	0,20594
1991-10-02 14:19	0,2	2061-10-02 14:19	0,20594

Figure 1 Example of original and downscaled rainfall time series from Kalmar, Sweden.

Besides the time series, the user will be provided with a table of percentage changes in different key rainfall properties (mean, maximum and frequency), separated into seasons. Table 1 shows these changes obtained in Kalmar during the development of the CS functionality.

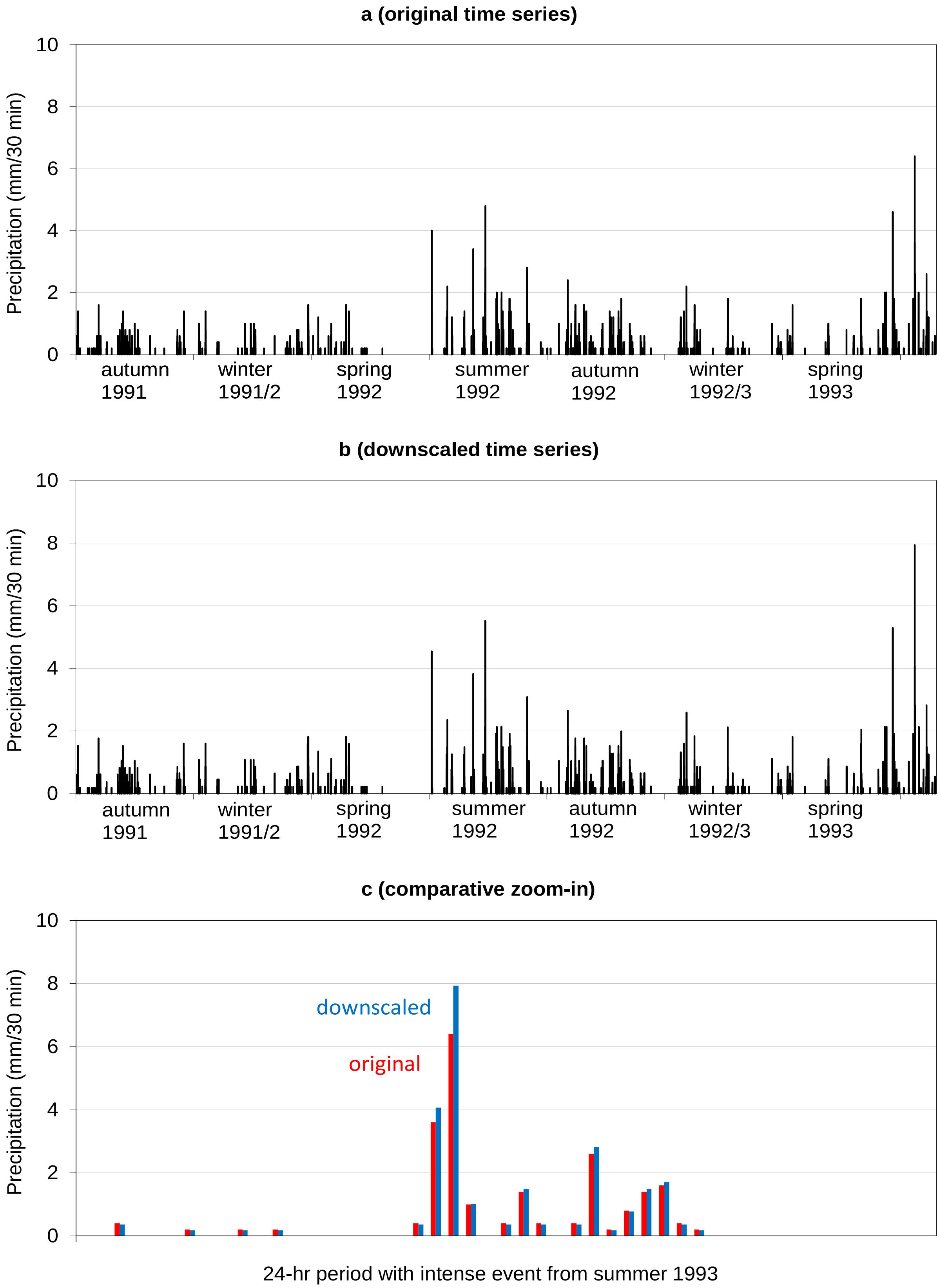


Figure 2 Time series visualisation of original data (a), downscaled data (b) and a comparison (c).

Table 1 Example of general rainfall changes from Kalmar, Sweden

	Mean rainfall	Maximum rainfall	Frequency of rainfall
Winter (Dec-Feb)	+3.1%	+9.3%	-1.5%
Spring (Mar-May)	+6.9%	+17.8%	+2.2%
Summer (Jun-Aug)	-1.2%	+17.5%	+2.3%
Autumn (Sep-Nov)	-1.5%	+6.1%	+1.6%

Further, time series visualisation is supported (Figure 2). This visualisation is based on a 30-min time step, which is the time step used in the RCM precipitation downscaling. It is possible to view original and downscaled time series in the full period or in an arbitrary part of the full period (Figure 2a and 2b). It is also possible to zoom in on individual seasons or events and compare the original and downscaled series in the same diagram (Figure 2c).

In the final version of Common Services, the time series downscaling will be extended to take into account also future changes in rainfall frequency, i.e. number of dry and wet (rainy) periods. The analysis of climate scenarios indicates that future changes are related to a changed number of rainfall events, rather than changes in the event duration. Therefore the frequency adjustment procedure will be based on a statistical analysis of rainfall events in the RCM output. Future changes in frequency will be simulated by either removing or duplicating events in the historical series. This document will be updated when the procedure is fully developed, tested and implemented.

4.2. Event-based case: IDF curve downscaling

In this case, the aim is to estimate the future change of the rainfall intensity of individual, extreme events as represented by the Intensity-Duration-Frequency (IDF) curve (Figure 3). This type of curve, which is widely used in urban hydrological engineering, gives the rainfall intensity as a function of event duration and return period (i.e. frequency). Figure 3 shows a 10-year curve (i.e. representing events that occur on average once every 10 years) and for today's climate the intensity associated with a 45-min rainfall is 34 mm/hr (observed IDF curve), implying that every 10^{th} year 25.5 mm of rainfall fall during 45 min in this location.

In the Common Services, the DC method is implemented to transfer future changes in short-term extreme rainfall statistics to the historical IDF curve. This is based on extreme value analysis of 30-min rainfall in RCM output using the Extreme Value Type 1 distribution (also called Gumbel distribution). The result is a relative intensity change as a function of duration and return period, which may be used to obtain a downscaled IDF curve by translating the historical curve (Figure 3).

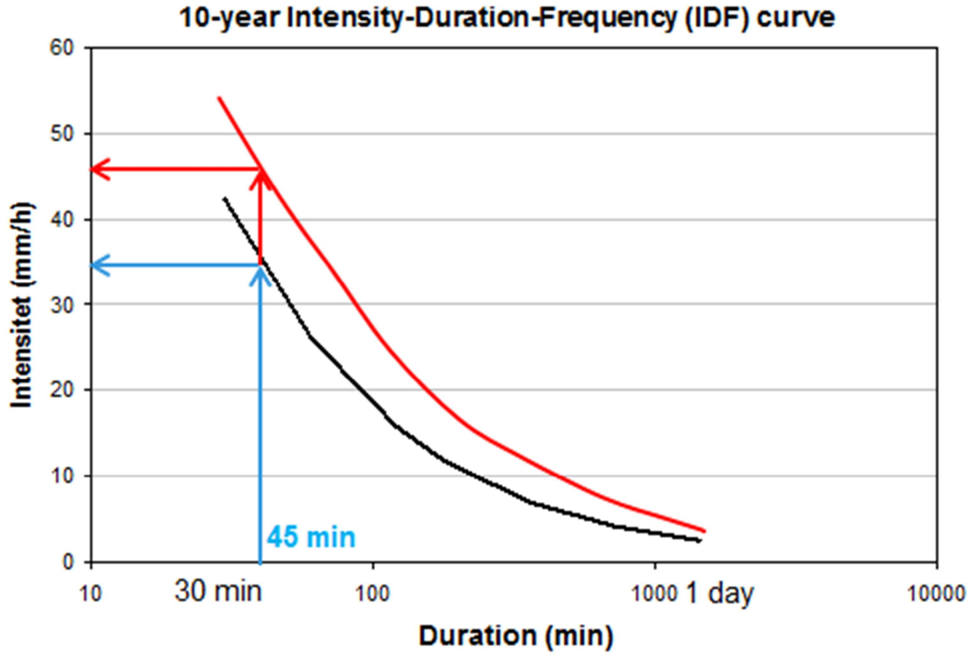


Figure 3 Example of observed (black) and downscaled (red) 10-year IDF curve

In the Common Services, the IDF curve is considered a table of IDF values with intensities (unit: mm/hr) associated with different combinations of duration and return period (Figure 4). The input to the service is a table with observed values. It should be emphasised that in practice the entire set of IDF curves are not always of interest. The entire set may be interesting in e.g. national applications, development of recommendations etc. But in local engineering applications it is often only a certain combination of duration and return period that is interesting to downscale. The duration is related to the size of the catchment and the relevant return period is typically given by design guidelines. In these cases the IDF table will thus only consist of one single value, as indicated in Figure 4.

Observed

	1 year	10 years	50 years	…
10 min	39	54	79	…
30 min	29	41	63	…
60 min	24	30	45	…
…	…	…	…	…

Downscaled

	1 year	10 years	50 years	…
10 min	44	60	87	…
30 min	34	46	70	…
60 min	27	34	51	…
…	…	…	…	…

Figure 4 Example of observed and downscaled IDF table

As the climatological time scale used in the rainfall downscaling is 30 years, the user must associate the uploaded IDF table with a 30-year period which becomes the reference period in the downscaling. If the exact period of the observations from which the IDF values have been calculated is known, the mid-point of this period should define the centre of the reference period. This exact period is however not always explicitly given and may not be easy to obtain; if so a best guess is required.

The main output is a table with downscaled IDF values (Figure 4) available for download. If an entire IDF curve (or set of curves) is used as input a diagram with observed and historical curve(s) may be plotted (Figure 3).

5. Technical solutions

The rainfall downscaling is a part of the SUDPLAN Common Services (CS). 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 5). A standardized communication will assure an easy setup connection to the Common Services, also for other software which require climate services of this type.

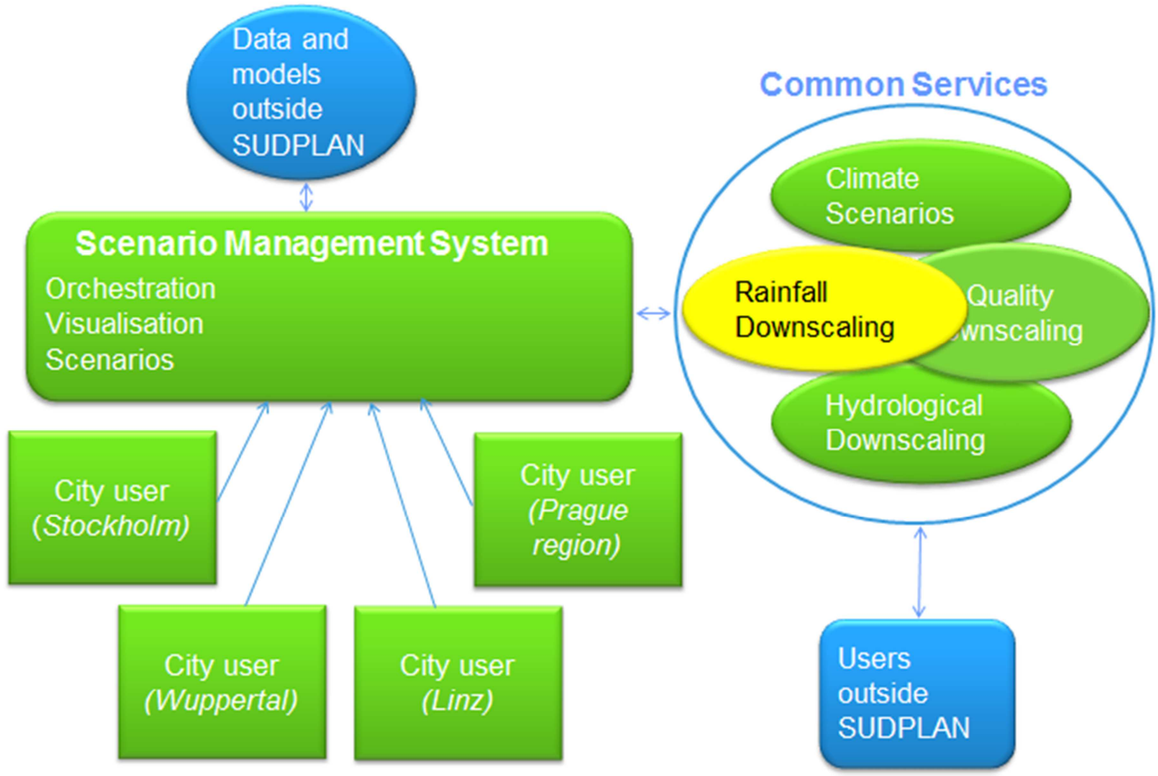


Figure 5 Overview of SUDPLAN components. The communication between Common Services and the Scenario Management System uses standardized services (OGC).

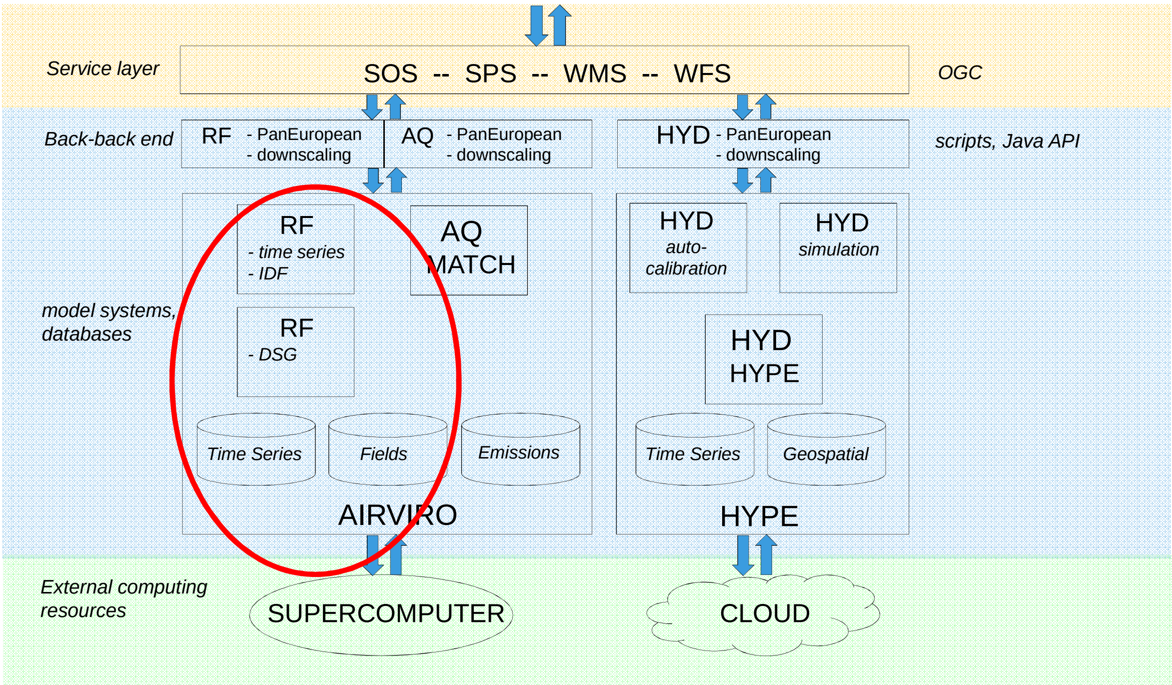


Figure 6 Technical solution of Common Services, with rainfall downscaling components marked.

The technical structure of Common Services is illustrated in Figure 6. 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 separated 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 rainfall downscaling components (marked in Figure 6) forms part of the Airviro model system, which also support the air quality downscaling. This document describes how the downscaling is performed in SUDPLAN. Technical descriptions concerning all components of the rainfall 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 domain and parameters, input data (historical observations), 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 rainfall downscaling will be presented by WP6 and WP7.

[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 during 2012.

5.1. Overview of components and data flows in rainfall downscaling

Figure 7 shows the principles for the intense rainfall downscaling. Two types of user specifications are needed to launch a model simulation:

1. User selections: CS receives from SMS the coordinates for the station, the data from which are to be downscaled, together with some identification of the coordinate system and map projection. The user has also specified which climate scenario to use, a reference year (*only IDF table*) and a target year specifying which future 30-year time period to perform the downscaling for.

2. User data: (1) Short-term rainfall observations from a tipping-bucket gauge or equivalent on a specified format, time stamp (resolution: minute or higher) followed by a rainfall registration (mm) (Figure 1) or (2) IDF table with combinations of duration (min), return period (year) and intensity (mm/hr) (Figure 4).

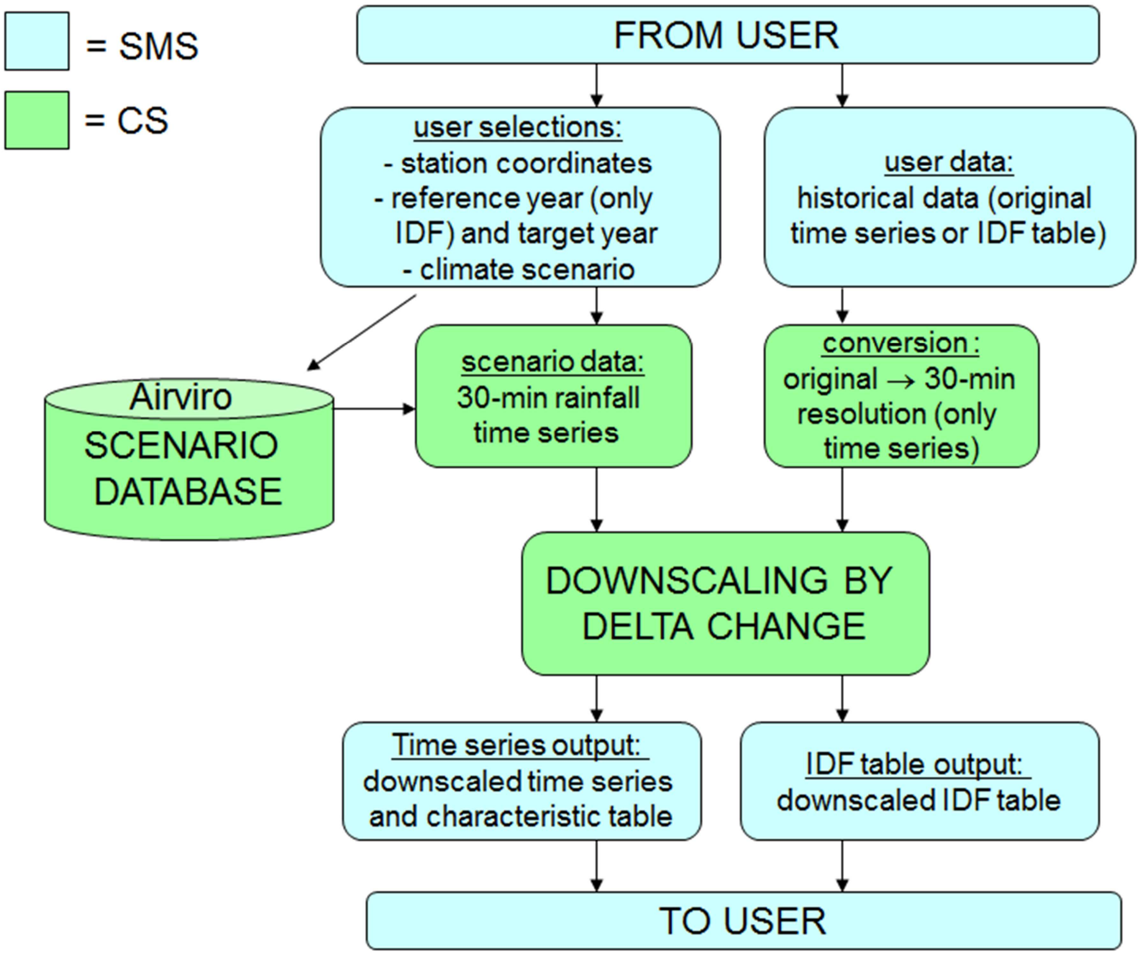


Figure 7 Components and data flows between SMS and CS for intense rainfall downscaling

The model execution includes the following steps:

- Extraction of 30-min rainfall time series from the CS Scenario Database, in five RCA grid boxes surrounding the location.
- Conversion of historical time series to 30-min time resolution, to be compatible with scenario data (*only time series*).
- Downscaling by Delta Change, including (1) estimation of future changes from the scenario data and (2) transfer of the estimated changes to the historical data.
- Calculation of general rainfall changes from reference to scenario period (*only time series*).

In the next section, each step in the procedure is illustrated in the SMS context.

5.2. Step-by-step procedure in SMS

The rainfall downscaling involves a number of steps in the SMS. In Figure 6, these steps are illustrated as presently implemented in the user interface (it is assumed that observed data have been already uploaded).

1. Find the observed data (time series or IDF table) in the left-hand column, drag and drop it to the point of interest on the map. An illustration of the data is provided.

2. Choose 'Start downscaling'.

3. A list of climate scenarios appear, choose the desired one.

4. [*Only IDF table*]: select a reference period.

5. Select a target year, defining the centre of the future 30-year period.

6. [*Only time series*]: view the results as time series and table with changes.

7. [*Only IDF table*]: view the results as IDF table (a) and optionally IDF curves (b).

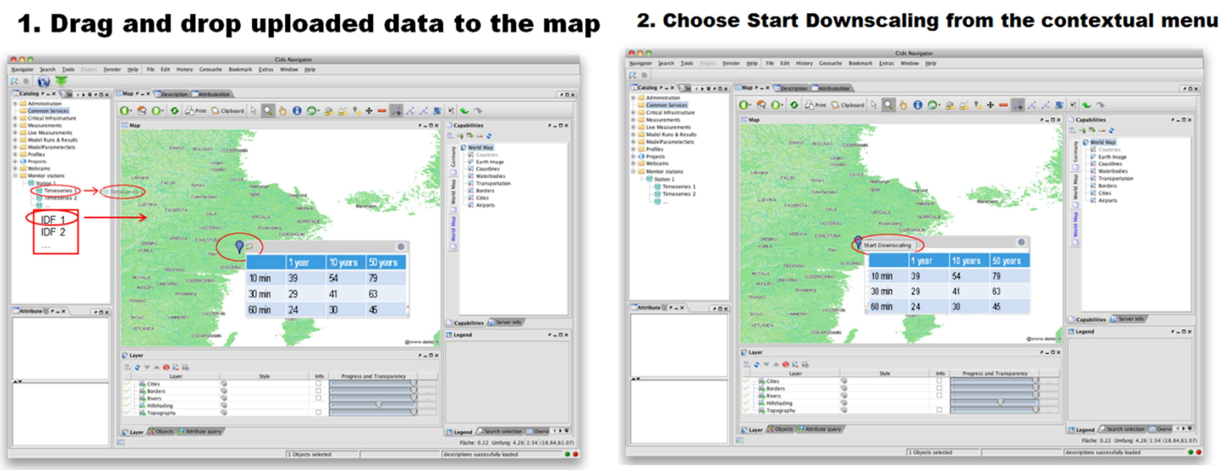
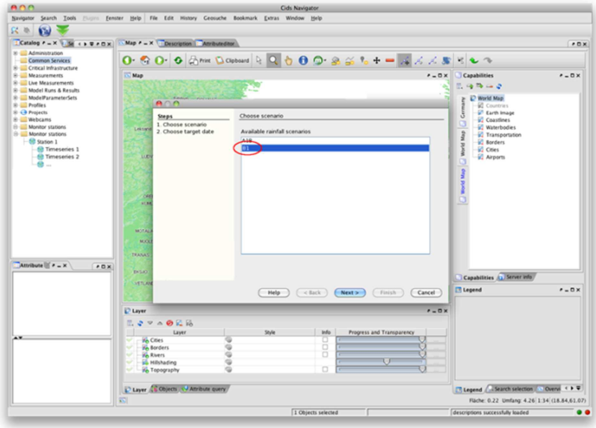
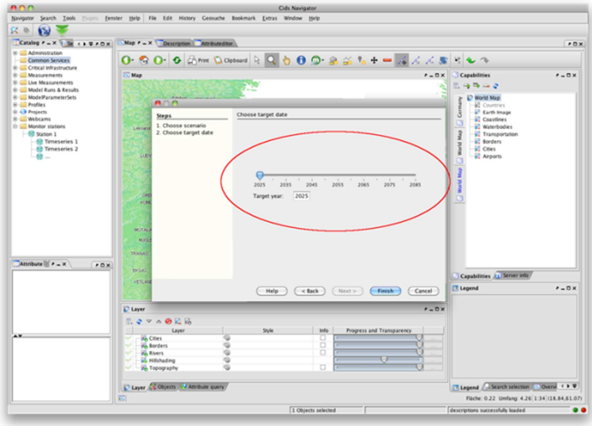


Figure 6 Step-by-step procedure of rainfall downscaling in the Common Services interface.

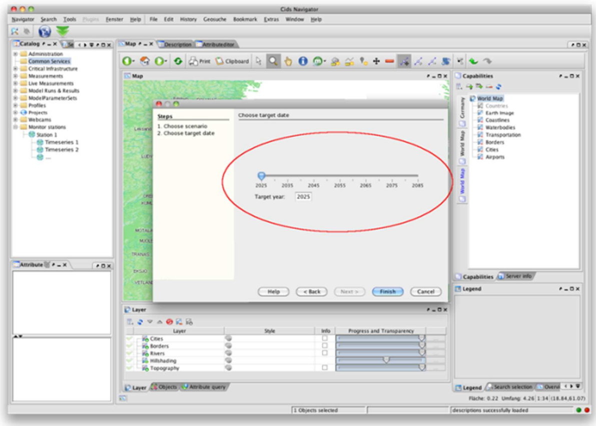
3. Choose scenario



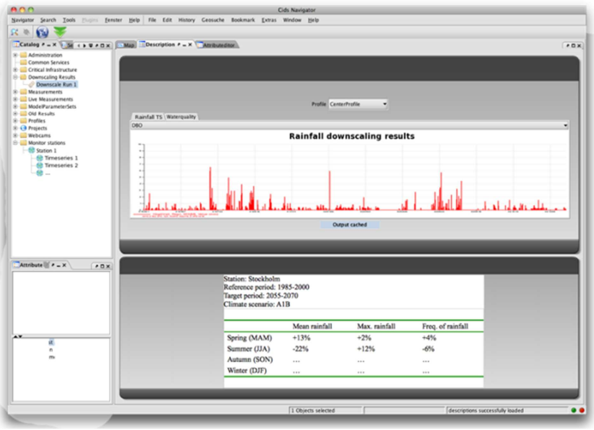
4. Choose reference date (*only IDF table*)



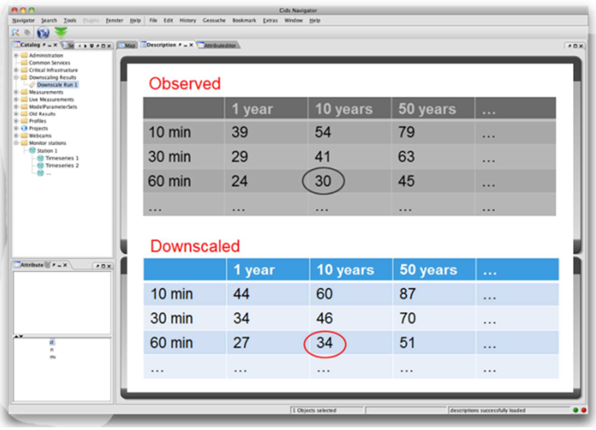
5. Choose target date



6. View the downscaling results



7a. View the downscaling results



7b. View the downscaling results (*optional*)

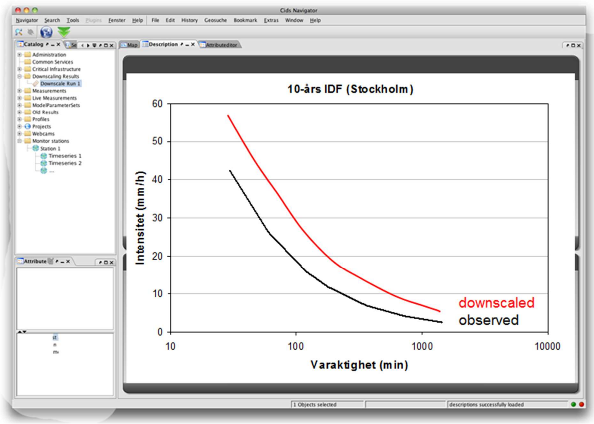


Figure 6 Step-by-step procedure of rainfall downscaling in the Common Services interface (continued)

6. Design storm generator

The case of event-based rainfall downscaling (section 3.2) is complemented by a Design Storm Generator (DSG). The principal functionality has been already implemented but service as well as user interface integration will be made during 2012. The IDF curve downscaling gives the expected future volume of a rainfall event of a certain duration and return period. In urban hydrological modelling (e.g. sewer system design), this volume needs to be converted into a time series for the event. In this case, standardised so-called design storms are typically used to define the temporal pattern of rainfall intensities (Figure 7). Essentially, a design storms defines how large fraction of the total storm volume that falls in each time step during the event.

In the DSG, it will be possible to generate design storms representing future climate. Two DSG versions will be available, one static and one dynamic. In the static case the catchment is considered homogeneous with respect to the rainfall intensity, i.e. rainfall movement is not taken into account but at a certain time step all parts of the catchment experience the same intensity. This is how design storms are typically used today. In this case generation of future design storm is straight-forward, it is a simple re-scaling of the storm to be consistent with the future total volume (Figure 7).

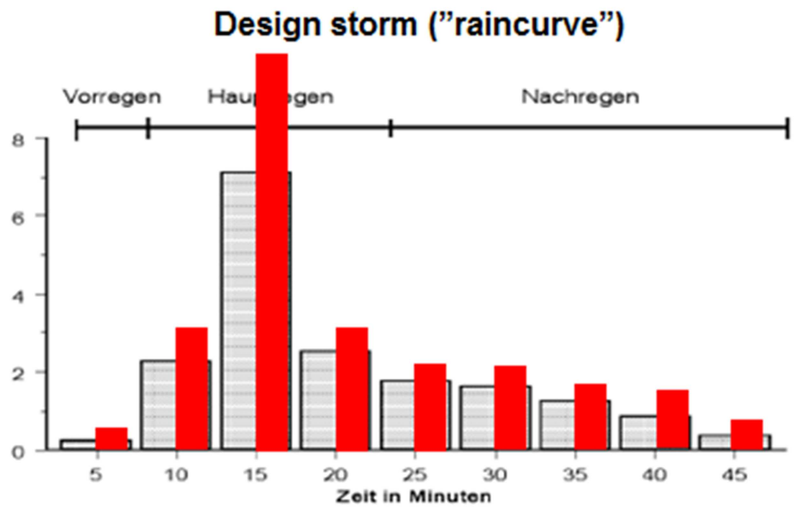


Figure 7 Example of historical (grey shaded) and generated (red) design storm (historical storm from DWA, 2006).

It should be emphasised that the future total storm volume may be estimated using the Common Services IDF downscaling functionality but this is not mandatory. Guidelines or recommendations may require some other specific procedure for the estimation of future design storm volumes, such as using fixed climate factors for the upscaling. Therefore the DSG is to be independent of the Common Services IDF downscaling functionality, to ensure applicability and flexibility of the tool.

The second DSG version represents a spatio-temporal extension of the design storm concept. In the dynamic case the catchment is considered heterogeneous with respect to the rainfall intensity, i.e. rainfall movement is taken into account and at a certain time step different parts of the catchment experience different intensities. Rainfall movement may have a significant impact on e.g. the discharge response in the sewer system and should therefore be taken into account in a

complete functional evaluation. The dynamic version is implemented by calculating the time lag in different parts of the catchment (based on given storm direction and speed) and then adjusting the static design storm appropriately. The output is dynamic versions of static design storms as shown in Figure 7, in the form of space-time matrices (Figure 8).

Historical (simulated)

Grid box:	1	2	3	4	…
Time (min)	P (mm)	P (mm)	P (mm)	P (mm)	P (mm)
0	0	0	0	0	…
10	19	0	0	0	…
20	36	19	0	0	…
30	60	36	19	0	…
40	36	60	36	19	…
…	…	…	…	…	…

Downscaled

	1	2	3	4	…
Time (min)	P (mm)	P (mm)	P (mm)	P (mm)	P (mm)
0	0	0	0	0	…
10	28	0	0	0	…
20	53	28	0	0	…
30	80	53	28	0	…
40	53	80	53	28	…
…	…	…	…	…	…

Figure 8 Example of historical (simulated from historical static design storm) and downscaled dynamic design storms as space-time matrices.

Some complementary development concerning the input and the output is needed. In terms of input, it is suggested to define the catchment in terms of a grid (Figure 9). One grid box implies a homogeneous catchment, i.e. a static design storm; more than one a catchment with heterogeneous rainfall intensities, i.e. a dynamic design storm. Grid-based areal delineation is used also in the Air Quality Common Service so this functionality may conceivably be applied also in the DSG. Concerning output, support must be developed to download space-time matrices with rainfall intensities in different grid boxes during different time steps (Figure 8). Finally, it will be attempted to develop support for 4-D animation of the dynamic design storms, projected onto the actual catchment (Figure 10).

The step-by-step SMS procedure for the Design storm generator is conceptually similar to the case of rainfall downscaling (Figure 6). In Figure 11, the steps are illustrated as intended to be implemented in the user interface (it is assumed that a historical design storm has been already uploaded).

1. Zoom in to area of interest.

2. Make a grid over the relevant catchment (see Figure 9).catchment

3. Find the historical design storm in the left-hand column, drag and drop it to the grid. An illustration of the storm is provided.

4. Choose ‘Start downscaling’.

5. Choose the future total volume to be used.

6. Choose the storm direction

7. View the results as static design storms (a) and optionally 4-D animation, if dynamic design storm (b).

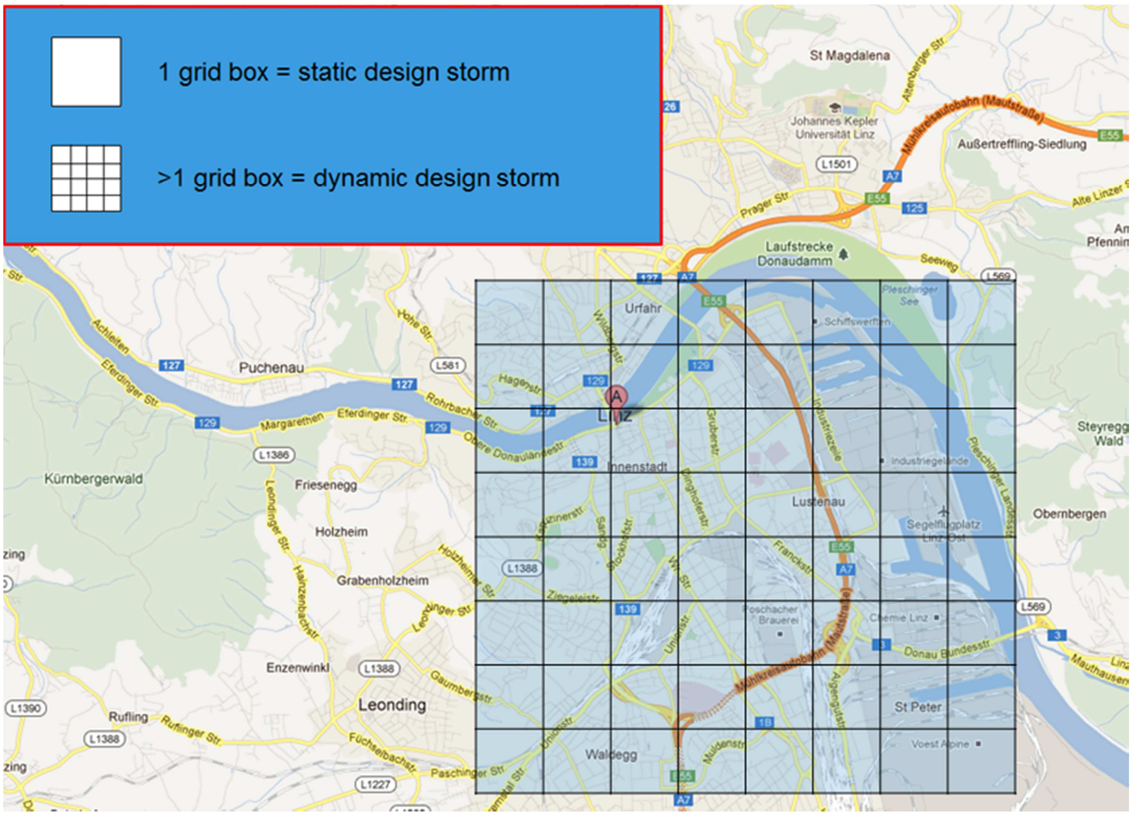


Figure 9 Catchment delineation in the Design storm generator. The number of grid boxes determines the type of design storm generated (static, dynamic).

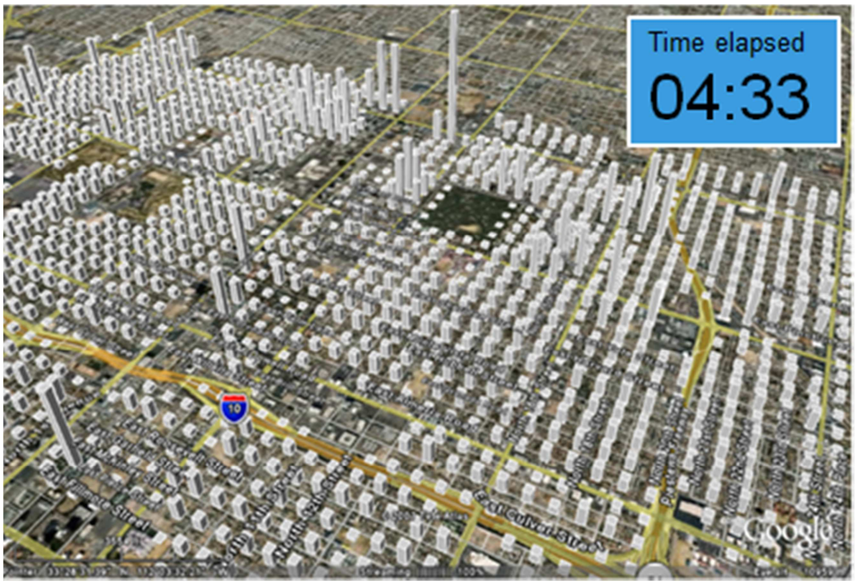


Figure 10 Possible method for animation of a dynamic design storm (note that the visualised data in the illustration has nothing to do with rainfall).

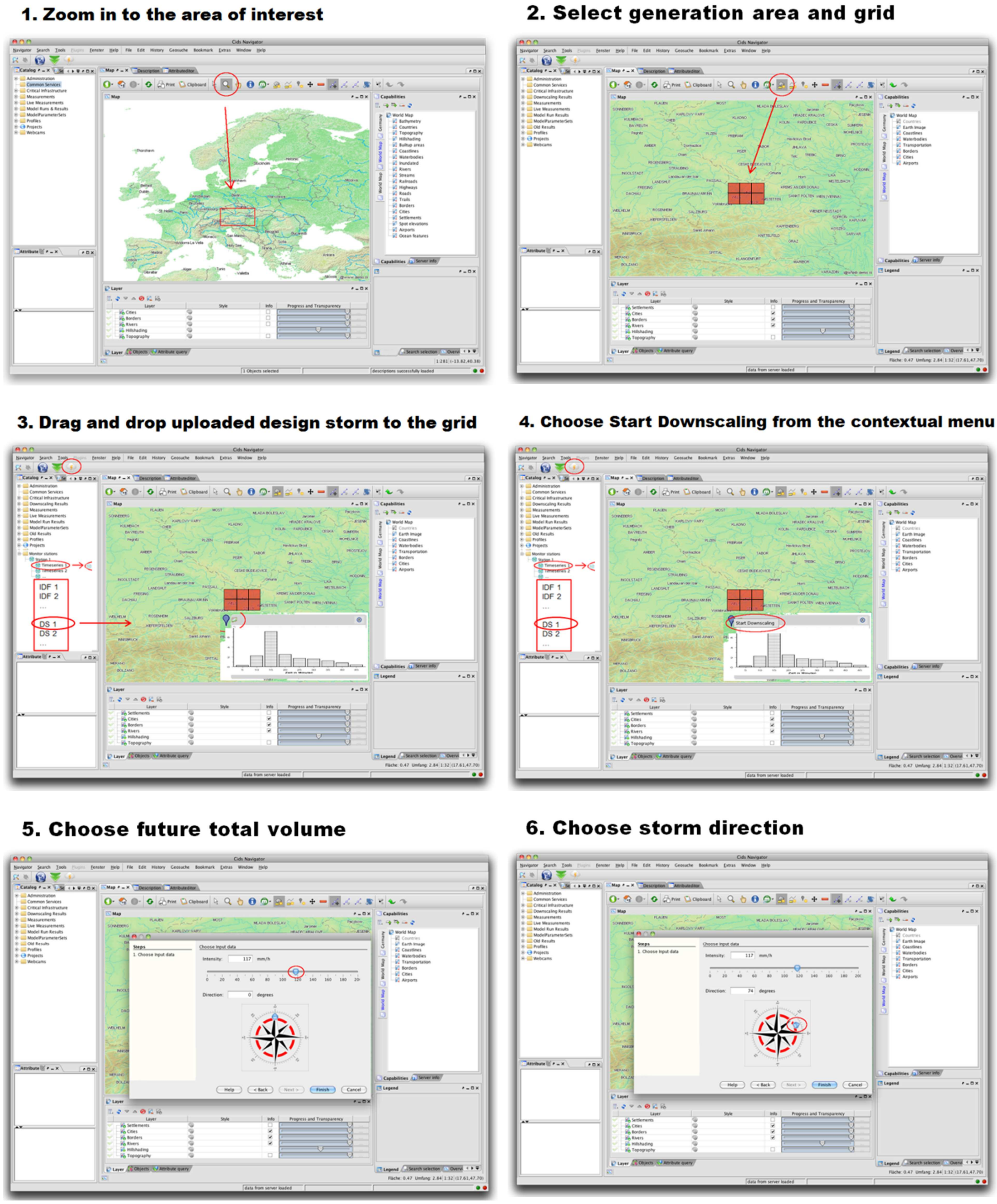


Figure 11 Step-by-step procedure of the Design storm generator in the Common Services interface.

7a. View the downscaling results (*always*) **7b. View the result in the map (*dynamic*)**

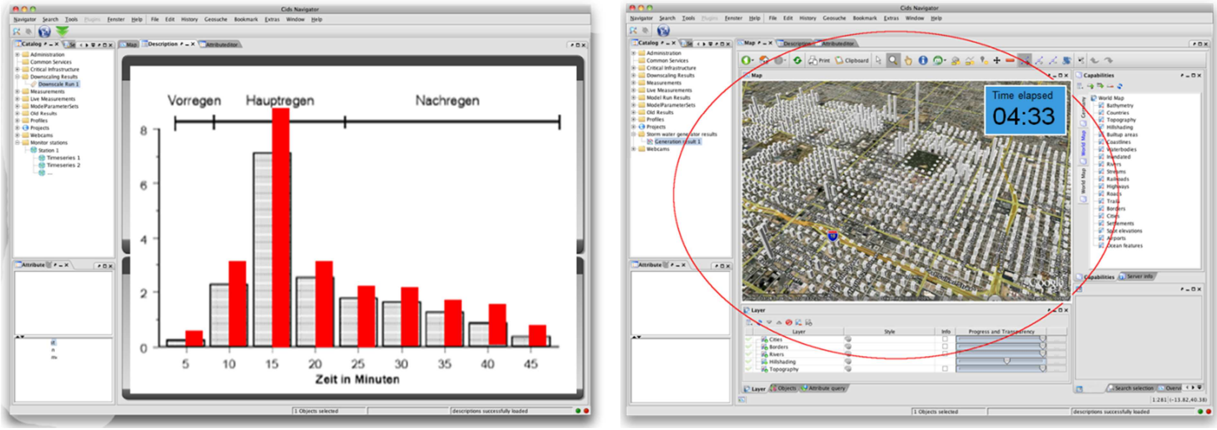


Figure 11 Step-by-step procedure of the Design storm generator in the Common Services interface (continued).

7. Conclusions

The urban rainfall downscaling mechanism in the Common Services V2 is now (m24) fully operational. In addition, the use of the SUDPLAN platform to manage rainfall downscaling is presented by the two pilots, WP6 (Wuppertal) and WP7 (Linz) (see e.g. their pilot V2 reports D6.2.2 and D7.2.2). Moreover, future rainfall projections have been made for both Wuppertal and Linz that are of direct interest for those two pilots and associated external stakeholders. In Linz the downscaled rainfall data have been used in sewer modelling and assessment of future combined sewer overflow rates. The design storm generator routines have been implemented and tested.

For 2012 the design storm generator will be integrated into the Common Services. Further, the time series downscaling will be upgraded with support for rainfall frequency adjustment.

8. References

D4.1.2 Common Services concerted approach V2.pdf

D6.2.2 Wuppertal Pilot Definition V2.pdf

D7.2.2 Linz Pilot Definition Plan V2.pdf

DWA, 2006. Arbeitsblatt DWA-A 118, Hydraulische Bemessung und Nachweis von Entwässerungssystemen, Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V., Theodor-Heuss-Allee 17, 53773 Hennef, Germany.

9. 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 *IPCC emission*	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.

scenarios *European tracer gas emissions (air pollutants)* *Local 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)* 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* (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.

10. 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.
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

