# DEVELOPING AN SDI FOR TIME-VARIANT AND MULTI-LINGUAL INFORMATION DISSEMINATION AND DATA DISTRIBUTION

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**ABSTRACT**

The Institute for Geoinformatics (IFGI) of the University of Münster develops an SDI in the context of a research project for the assessment of climate change vulnerabilities in the Arctic. The SDI has to distribute, portray and process spatial-temporal data for multi-lingual stakeholders from different knowledge communities. This combination of tasks forms a distinctive ground for research questions and resulted in a number of solutions coupled with hands-on experience.

**KEYWORDS:** SDI, OGC, multi-lingual, internationalisation, spatial-temporal data, service chain, knowledge communities.

## INTRODUCTION

The number of spatial data and service infrastructures (SDI) is increasing (Groot and McLaughin 2000; Bernard, Annoni et al. 2004) and the experience in this field of expertise is growing together with the number of identified SDI-specific problems and proposed solutions. Nevertheless in times of INSPIRE, a new dimension of harmonisation efforts revealed itself. The following paper addresses some of the aspects that come along with building a service infrastructure for an international user community.

The Institute for Geoinformatics (IFGI) develops an SDI in the context of the research project BALANCE[1] for the assessment of climate change vulnerabilities in the Arctic. The BALANCE consortium assesses ecological and socio-economical changes in the Barent Sea Region based on the results of a regional climate model. The project results are used to inform experts, governmental organisations and lay people in four different countries about the expected changes and their potential impacts (BALANCE 2002). The requirements for the SDI can be formulated as follows: The web services have to distribute, portray and process time-variant spatial data for multi-lingual stakeholders from different knowledge communities. To ensure extendibility, sustainability and interoperability we made use of standards and de-facto standards published by organisations like ISO[2] (International Organisation for Standardisation) and OGC[3] (Open Geospatial Consortium).

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[1] http://www.balance-eu.info
[2] http://www.iso.org
[3] http://www.opengeospatial.org

The following sections will describe the requirements in more detail and discuss the chosen solutions: The first section addresses the challenge of time-variant data distribution and portrayal and describes the implemented infrastructure of Model and Workflow Information Services, and Human Interaction Services (ISO/TC-211&OGC 2002). The second section discusses different levels of multi-language support in international SDI and presents the solution we chose for the BALANCE SDI. The third section describes our attempts to serve stakeholders from different knowledge communities by providing them with information considering their interests and their background. The fourth section examines briefly the attempts of generating user specific information and the paper ends with a conclusion concerning the expected social impacts.

## THE CHALLENGE OF TIME-VARIANT DATA DISTRIBUTION AND PORTRAYAL

The results of a regional climate model (REMO) for the Barent Sea Region, provided by the Max Planck Institute for Meteorology (MPIfM) in Hamburg (Jacob 2004), are the driving force for a number of socio-economical and ecological models created by the members of the BALANCE consortium. It therefore forms the major source of spatial-temporal data in the BALANCE SDI. The temporal extent of the distributed[4] REMO results is 1961-01 to 2099-12 in a monthly temporal aggregation. Generated in binary format, the data comprise several records whereat every record includes data assigned to a timestamp. This type of temporal data model is called snapshot model and it treats time as an attribute rather than a dimension of its own (for details please refer to (Jacob 2004; Tegtmeyer 2005) ).

The users of the BALANCE SDI shall be able to request the spatial and temporal extent of a (climate) parameter of interest and either save the result for further use (e.g. in a desktop GIS or a service chain) or visualise it, both in an appropriate format. Therefore we distribute the modelling results in a grid coverage format to BALANCE partner institutes; the other BALANCE stakeholders are presented with static maps for time-invariant information and with animations for time-variant information.

### Distribution of spatial-temporal data using the OGC Web Coverage Service Interface

The OGC Web Coverage Service (WCS) specification version 1.0 (OGC 2003b) [5] has been implemented for the BALANCE SDI. It allows the distribution of digital Grid Coverages (OGC 2001). The specification describes three operations: 1) *GetCapabilities*, 2) *DescribeCoverage* and 3) *GetCoverage*:

1) The *GetCapabilities* operation has been established by the OGC as an operation common to all OGC Web Service (OWS) interfaces to provide clients with a self-description of the requested OWS instance in a machine-readable way (see (OGC 2005)). The self-description includes amongst other things metadata about the service binding, the data offered by the service (name, abstract, etc.) and the data producers. This is common to all OGC services that implement the OWS Common specification.

2) The *DescribeCoverage* operation is, other than the *GetCapabilities* operation, specific for a WCS. The document returned when sending a *DescribeCoverage* request contains a more detailed description of a certain Coverage including the description of its spatial and temporal extent.

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[4] The distributed results differ from those that have been modelled in terms of spatial and temporal aggregation.
[5] At present, the OGC is working on WCS Specification 1.1.0.

3) The *GetCoverage* operation allows a client to request Grid Coverages based on the information included in the *Capabilities* and the *DescribeCoverage* documents. Such a request contains, amongst other things, the spatial and the temporal extent of the desired Coverage. The WCS specification describes the following options for time parameterisation:

- A time instant like *1961-01-01*.
- Multiple time instants like *1961-01-01, 1962-01-01, 1963-01-01*.
- A time interval described by a *begin-time*, an *end-time* and optionally a *temporal resolution* written as *1961-01/1961-12/P1M*. *P1M* stands for *Period = 1 Month* and describes the desired temporal resolution.
- A series of time intervals. This one allows the request for different time slices, a technique often used for meteorological data production to reduce the amount of data.

The output format of our WCS is GeoTIFF (TIFF = Tagged Image File Format), see (Ritter and Ruth 1995; Mahammad and Ramakrishnan 2003). It is appropriate for distributing time-variant data in a snapshot model, as it allows the storage of single or multiple georeferenced images or bands in one file. To store and retrieve metadata about the temporal extent, we extended the GeoTIFF format with a number of tags that allow the specification of a timestamp tied to an image (for a full description see (Tegtmeyer 2005)).

Resuming the named functionalities, the implemented WCS qualifies as an appropriate mean for the distribution of spatial-temporal data and therefore meets the requirements described above. Based on this interface, we developed a simple web client that enables the BALANCE partner institutes to request Grid Coverages by area and time (resp. time sequence or interval) of interest. Additionally the interface is used for further processing, as described in one of the following sections.

**Portraying spatial-temporal data provided by the WCS using the OGC Web Map Service Interface**

The OGC Web Map Service (WMS) specification 1.3.0 and its predecessors aim to produce visual representations (maps) of georeferenced data. Like the WCS Interface, the WMS Interface provides three operations. But while the WCS has dedicated two of its three operations to providing metadata for the service itself and the offered data, the WMS only provides metadata through the *GetCapabilities* operation. Therefore all information required to access and display data of a WMS is usually described either within the WMS *Capabilities* in case of a tight coupling between the service and the data, or within a Styled Layer Descriptor (SLD) document in case the coupling is loose. In the latter case, the WMS is used to display data provided by another WMS, WCS or Web Feature Server (WFS), see (OGC 2002b). However, an SLD document is not bound to loose coupling, but can also be used in cases of a tight coupling.

To prevent redundancies we portray the spatial-temporal data provided by our WCS using the WMS Interface. The preferred choice was a loose coupling between WCS and WMS using SLD documents for the portrayal. Unfortunately this turned out to be problematic: The SLD specification has very limited means for describing the representation of raster data. Furthermore, though the options for requesting time are basically the same for WMS and WCS (see list above), the parameterisation of temporal requests is not homogeneous between the two services. Therefore a client can generate a request that is valid for a WMS but can not be passed on to a WCS without modifications[6]. Due to these limitations (and then some more, see (Rietz 2004)), an OGC Interoperability Program Report called Coverage Portrayal Service (OGC 2002a) was drafted in 2002. The document suggests the use of the common WMS interface in combination with an extended SLD for the portrayal of Coverages. Unfortunately this is still a draft version 0.0.2 and has not been further edited since 2002. It therefore does not meet our goal of ensuring interoperability. Nevertheless either a follow up on the CPS document or a redesign of the current SLD specification would be required for a successful loosely coupling of WCS and WMS interface. Considering these reasons, the WCS-WMS service chain in this specific service infrastructure has been tightly coupled. This means that the WMS is only able to visualise the data of our specific WCS, which's location, data supply, spatial and temporal extent, temporal resolution and rules for visualisation (styles and corresponding colour maps) are known to the WMS.

The visualisation involves static maps (pictures) with single timestamps and dynamic maps (animations) presenting multiple time instants or time interval(s). While the first case has been implemented many times in SDI, the latter case is an area of ongoing research. For the visualisation of time-variant data within the BALANCE SDI we make use of Scalable Vector Graphics (SVG). SVG is an XML dialect and official standard of the World Wide Web Consortium (W3C)[7]. It is used to create two-dimensional, scalable vector graphics. SVG acknowledges vector graphics, raster pictures and text as graphical objects and it is capable of producing animations. The visualisation takes place through the web browser, a browser Plug-In or an independent SVG-Viewer. At present the Adobe SVG Viewer 3.0 (browser Plug-In) supports most of the available SVG features, e.g. the option to zoom into an animation or to stop and restart it.

To clarify the process, figure 1 describes an exemplary service chain involving WCS, WMS and WMS-Client. The following description makes use of the numbers in the figure: (1) A user chooses the time-variant WMS to add it to the WMS-Client. (2) The WMS-Client sends a *GetCapabilities* request to the chosen WMS. (3) The WMS returns the *Capabilities* document. The document references and describes those layers that are available from the WCS through the tight coupling. The description includes styles for the visualisation of the layers and formats that can be requested. (4) The user chooses with the help of the WMS-Client the layer and style, spatial extent and timestamp of interest for him. (5) The WMS-Client sends a corresponding *GetMap* request to the WMS which (6) the WMS transforms into a *GetCoverage* request to the WCS. (7) The WCS accesses the time variant data and extracts the temporal snapshot that was requested. (8) The WCS returns the corresponding GeoTIFF to the WMS. (9) The WMS transforms the GeoTIFF into the requested format (in this case Portable Network Graphics PNG) using the predefined style and colour maps and (10) returns the map in PNG format to the WMS-Client for portrayal.

[6] For details please refer to the WCS 1.0.0 *Capabilities* document XML Schema at (OGC) and the corresponding example *Capabilities* document at (OGC).
[7] http://www.w3.org

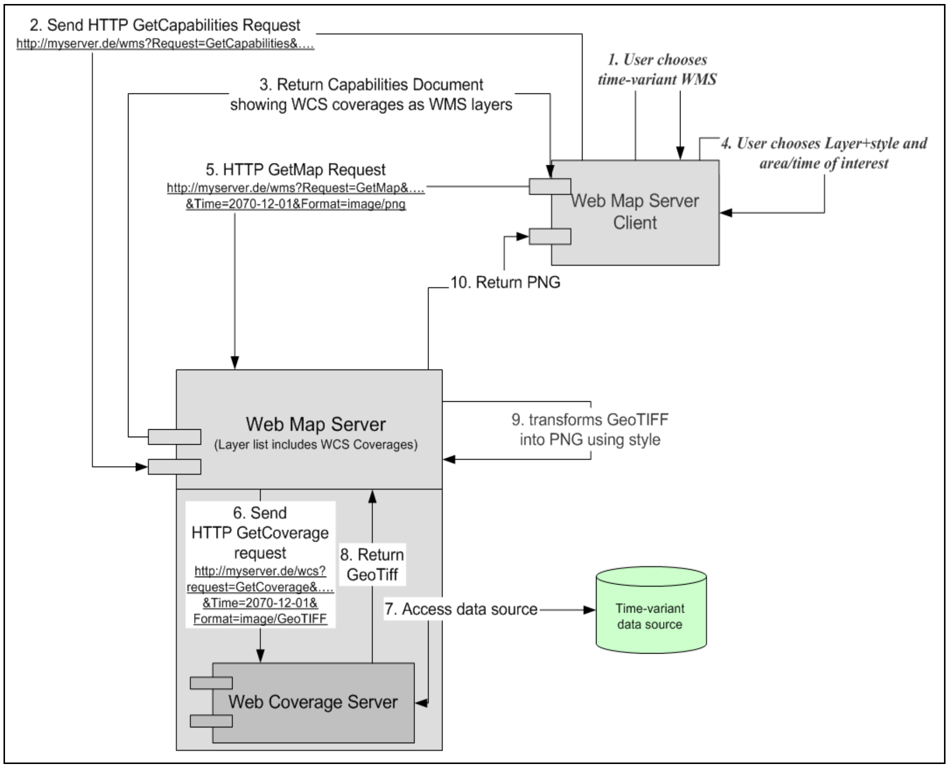


**Figure 1: Service chain WMS-Client, WMS and WCS, the process of requesting a time instant**

In figure 2, we exemplarily examine a WMS request for a time interval to the WMS, as this process is slightly more complex than the latter: (1) The user chooses the time interval of interest with the help of a WMS-Client, now equipped with an extra SVG Plug-In (herein called WMS-SVG-Client). (2) The WMS-SVG-Client sends the *GetMap* request for the time interval to the WMS. (3) The WMS resolves this request into as many different WMS requests for single timestamps as are explicitly encoded in the time interval (in this case: three). These requests are written into an SVG document that (4) the WMS returns to the WMS-SVG-Client. (5) The WMS-Client interprets the document and (6) sends a new *GetMap* request to the WMS according to the first entry in the SVG document. This request now contains a single timestamp. Steps (7-10) are equal to those in figure 1. The PNG returned in step 10 will be displayed in the WMS-SVG-Client for a specific time encoded in the SVG (e.g. 1 second) before the second *GetMap* request from the SVG document list is sent to the WMS. In this way, the WMS-SVG-Client sequentially goes through all *GetMap* requests encoded in the SVG and displays them one after the other in an infinite loop, which creates a continuous animation.

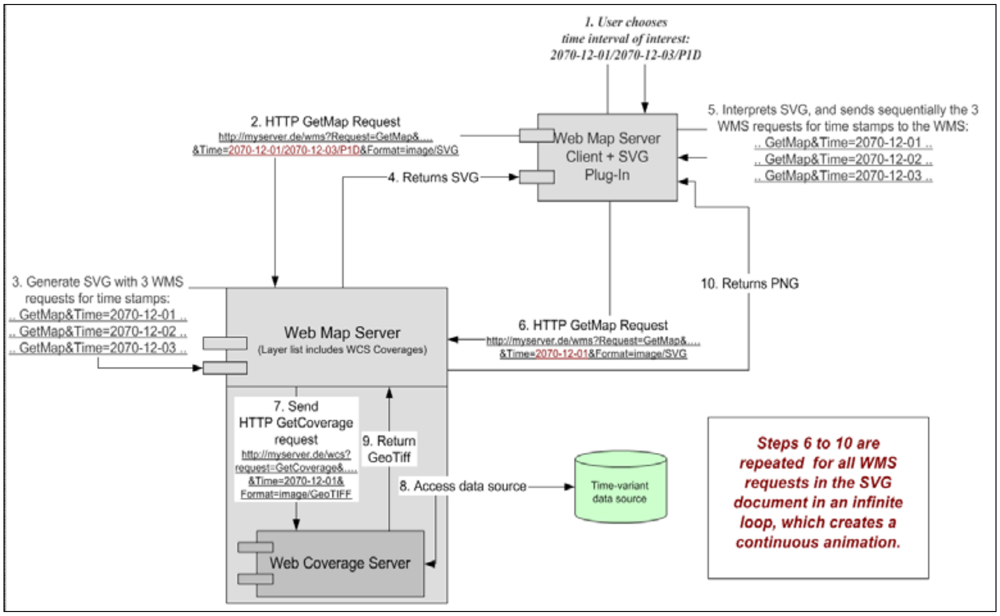


**Figure 2: Service chain WMS-Client with SVG Plug-In, WMS and WCS, the process of requesting a time interval**

The visualisation of multiple time instants or a time interval using SVG proved to be feasible. Additional information like the textual representation of a picture-specific timestamp can be easily added. Nevertheless, as there are different ways of generating an SVG-based animation, the client should know the structure of the SVG to process it as intended.

Altogether, the visualisation of time-variant raster data using a WMS-WCS service chain is not a smooth path. A stronger attempt of harmonisation between the OGC specifications WMS, WCS and SLD would surely be beneficial and ease the process considerably.

## ASPECTS OF MULTI-LANGUAGE SUPPORT IN INTERNATIONAL SDI

In the past the development of SDI focused on the technical interoperability, while problems arising from multi-lingual and inhomogeneous user groups did not seem very pressing. Nevertheless in the times of GSDI[8] and INSPIRE these issues are evidently of particular importance as SDI now face an international perspective with users from different countries accessing the same data sources. Providing the SDI with a multi-language enabling (a.k.a. internationalisation) is surely a key feature for a broader acceptance of SDI.

[8] Global Spatial Data Infrastructure: http://www.gsdi.org

There are several questions that need to be raised and answered before tackling the internationalisation task on a larger scale like the BALANCE SDI, or even the INPIRE initiative. Examples for such questions are the following:

1) What is the aim of the translation?

   Possible answers are: a) enabling data and service discovery in a multi-lingual fashion b) enabling multi-lingual data portrayal or c) enabling multi-lingual data analysis. Naturally more than one aim can be applied for the same SDI.

2) What is the translation strategy?

   Two techniques could be differentiated: a) Every multi-language feature in one language has to be translated into all other languages of interest, or b) all languages are translated into one common language.

3) How do you technically perform the chosen form of internationalisation?

   In case of aiming at the enablement of data discovery in a multi-lingual fashion (see 1a), the act of translation will probably be limited to keywords for the search in catalogues. The aim 1b) requires more effort and has been implemented for the BALANCE SDI described in this paper. The aim 1c) surely bears the highest complexity and the largest amount of translation work. This aim has been chosen by the eEarth initiative (see (Tchistiakov, Jellema et al. 2005)).

It is obvious, that the answers on those questions largely depend on the SDI. As mentioned above, the aim of the BALANCE SDI is to enable multi-lingual data portrayal. In our understanding, this includes at the very least the translation of data labels and corresponding legends. Furthermore the data portrayal user interface has to be translated into the languages of interest. Therefore we aim to provide multi-language support for WMS and WMS-Client:

The multi-language enabling of the WMS is done by translating the service metadata, which can be accessed through the *GetCapabilities* interface. The *Capabilities* document is utilised by the WMS-Client to enable interaction with the WMS service and to manage its data layers in a map view. Besides the layer title, the legend, the style title and some general service information have to be provided multi-lingual. This leads directly to a lack of the WMS specification, which disregards internationalisation mechanisms (see e.g. (OGC 2004)). Unfortunately, also the OWS Common Specification, which sets a general model for all OGC Services (see above), does not cover internationalisation of service metadata, but merely adds a parameter to specify the language of evolving service exceptions. Nonetheless, the OWS Common specification addresses the extension of operation requests and responses in a multi-language fashion as future work. In the meanwhile mechanisms have to be developed to fill this gap. Two practical approaches are described below.

In the first approach the multi-language enabling is tackled by the server through an extension of the WMS *GetCapabilities* request with a vendor specific parameter. Such a parameter could allow requesting the capabilities document in a desired language. This parameter would have to be processed by the server which would return the language specific service metadata. In case of a well-known number of service instances and a small number of service providers this solution seems appropriate. However, in an open community of potential service providers the use of vendor specific parameters usually blocks service interoperability and therefore can not be advised. Nonetheless, in case such an additional parameter or any other server-side multi-language enabling would become officially part of the OWS Common Specification, this solution would be the preferred option.

The second approach, which is taken in this paper and the corresponding prototype, is a client-side solution that has already proved useful for service internationalisation (Förster and Senkler 2003): The *Capabilities* Document of a WMS is translated into the desired number of languages and the translations are stored in a common XML encoded language file. When this WMS is added to the WMS-Client, it is associated with its language file. The file is processed by the WMS-Client and the elements are used to provide translations for e.g. layer titles and styles. Though this approach bears the necessity of hand-written language files, it is a straight forward approach in the context of BALANCE: It ensures interoperability and internationalisation with a limited effort, as the WMS contents for the majority of services in the BALANCE SDI are fixed due to the use of scenarios.

Nevertheless, not all service metadata is plain text: Some metadata elements like legends might be delivered in binary format. If binary legends contain textual descriptions e.g. for nominal or ordinal scaled layers, they should be provided in the required languages and referenced in the mentioned above language file. An alternative bear non-binary metadata elements. For example the SVG format can encode multi-language information which can be interpreted by the WMS-Client without extending the WMS specification on the server side. The disadvantage is that the WMS-Client and its SVG Plug-In have to be capable of recognising and displaying this information.

However, besides the service metadata, also the user interface of the WMS-Client has to be multi-language-enabled: The browser-based WMS-Client of the BALANCE-Project utilises the Jakarta Struts web framework[9]. The named framework provides an internationalisation concept to serve a multi-language web user-interface. In other words, Jakarta Struts is able to serve the static client content (besides the mentioned language files) in different languages. The internationalisation concept is flexible and easy to maintain, because it is separate from the other features of the framework. The user can choose the required language at each point of the session, changing text elements, buttons and labelling.

Future research in the field of internationalization might address a generic approach of using translation services based on ontologies resp. shared vocabularies, which could enable a conceptual translation of metadata descriptions. Depending on the complexity of the ontological structure, using ontologies for translation might outcompete current attempts for native translation services like *Babel Fish Translation*[10], because the context (e.g. domain, cultural aspects) is preserved.

## SERVING DIFFERENT KNOWLEDGE COMMUNITIES: CREATING A PROBLEM ORIENTED STAKEHOLDER PORTAL

### Describing the knowledge communities

As described above, the BALANCE stakeholder group is quite broad. Apart from distributing the results to the scientific community, we want to communicate the expected changes and potential impact to non-experts living and working in the area under consideration. The lay people

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[9] http://struts.apache.org

[10] http://babelfish.altavista.com

to be addressed are situated in many different countries and speak at least 5 different languages: Swedish, Norwegian, Finnish and Russian as well as Sami, the language spoken by the majority of the indigenous people in the Barents Sea Region. We also add the English language to this list to serve the international community of scientists and interested lay people. The groups we focus on are active in renewable resource industries as forestry, fishery and reindeer husbandry, which are very likely to be impacted by climate change.

**The resulting problem**

(Keskitalo 2004) describes interviews with people involved in reindeer herding, forestry and fishery. As she states in her paper, the sensitivities for changes related to climate change are different between the different groups as well as within one group between the different countries. Accordingly we have to formulate information for each of the groups in each of the countries and the corresponding language.

In an early project stage our team discovered, that neither scientists unfamiliar with GI service technology, nor lay people will use the BALANCE SDI according to the *publish–find–bind* paradigm as described in (OGC 2003a). We assume that the combination of a WMS-Client, a selection of WMS and a catalogue for data discovery does not raise enough interest, as it neither assists people in formulating a question, nor does it provide them with a corresponding answer. The questions they are interested in are quite diverse: How will climate change affect me as a reindeer herder/forester/fisherman? Is the presented information trustworthy? How has it been produced? These questions are quite straight forward, nevertheless the answers area not. The different stakeholders have a very diverse level of background knowledge. Therefore we need a representation of information, based on the data provided by the WCS, WMS and any other processing service that meets the expectations of those very different people.

**The chosen solution**

We embedded the information in a structure we call "Stakeholder portal"[11], where we provide the user with a guided information tour (see figure 3).

[11] http://geo-hermes.uni-muenster.de/portal

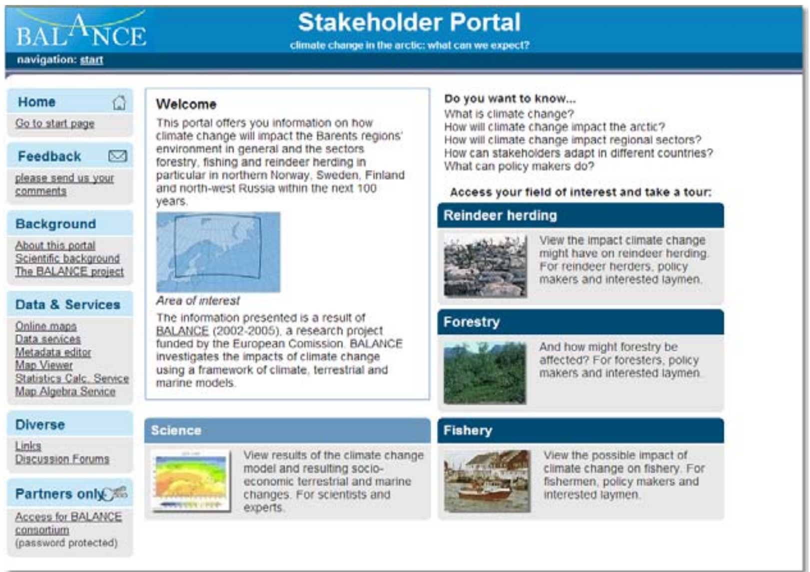


**Figure 3: Stakeholder portal, including the entry points for different user groups**

The tour shall help them to gather enough information to raise a question. Possible answers, and the requested additional information (metadata) like data production and source, will be presented in a hopefully familiar way: predefined maps. Of course one might argue that especially the requested metadata is already available. Nonetheless, their encoding and presentation seems not to be very understandable for people outside the GI resp. cartographic domain, who are often unfamiliar with notions like layer and metadata.

The predefined maps contain a title, textual descriptions and layer names according to the different user groups in the four countries. The maps are equipped with topographic background information, an automated abstract about the data producer, and an initial spatial and temporal extent. The maps can be opened, edited and saved as Web Map Context documents using the BALANCE Client, which implements the OGC Web Map Context Document specification (OGC 2003c). Such documents reference amongst others the connection details of different WMS data layers. In this way the user groups can be presented with an unbounded number of maps according to their level of knowledge while the underlying WMS layers stay untouched. The Web Map Context document has been extended for the BALANCE SDI with a multi-language <tag>, so that the WMS-Client language setting and the WMS specific language files will be saved as well. It is appointed in (OGC 2003c) that such extensions have to be ignored by a client if they can not be interpreted. Therefore these extensions do not interfere with the aimed interoperability.

## GENERATING USER-SPECIFIC INFORMATION

The BALANCE SDI aims to go beyond visualisation and provide users with new information based on existing data. We mentioned above, that the stakeholder groups have very broad range of problems and related questions. Our special interest lies in the fields of impact assessment and web-based decision support.

The climate change data provided by the WCS is already used for further processing: A Statistics Calculation Service developed by the IFGI as part of the Web Processing Services Interoperability Experiment (OGC 2004-01-31) is used to request climate change data from the WCS and returns statistic values. A web service implementing the map algebra concept of (Tomlin 1990) has been conceptualised and prototypically implemented (see (Holzmeier and Ostländer 2005)). Both processing services are part of a concept for the assessment of potential impacts and vulnerability to climate change. Further research undertaken in this particular area of interest covers the creation of online decision support systems by use of service chains and workflows (Bernard, Ostländer et al. 2003; Ostländer and Bernard 2005).

## CONCLUSIONS: EXPECTED SOCIAL IMPACT

The World Wide Web was chosen as an appropriate time- and space-independent platform to inform stakeholders in different languages reaching over borders that might not be easy to cross in reality. We furthermore consider the chosen representation of information connected to climate change through maps as a highly effective mean: The multi-lingual, time-variant and map-based approach of the BALANCE SDI will allow stakeholders to visualise information for their specific time and area of interest and in the appropriate language and hopefully increase their awareness for the changes their environment and their way of live might undergo.


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