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# Coupled component modelling for inter- and transdisciplinary climate change impact research: Dimensions of integration and examples of interface design

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ABSTRACT

In environmental research the importance of interfaces between the traditional knowledge fields in natural and social sciences is increasingly recognized. In coupled component modelling, the process of developing interface designs can support the communicative, social and cognitive integration between representatives of different knowledge fields. The task of integration is thereby not merely an additive procedure but has to be considered as important part of the research process. In our application, the development of a coupled component model facilitated an integrative assessment of the impact of climate change on snow conditions and skiing tourism in a typical Austrian ski resort. We elaborate the integration on two abstraction levels, a theoretical one and an applied one related to the case study. Other than model output, results presented here relate to the inter- and transdisciplinary development of the coupled component model and its interface design. We show how scientists from various disciplines and representatives from diverse societal fields jointly design interface tools. We identify joint model development – taking into consideration the different dimensions of integration – and recursive modelling as keys for successful inter- and transdisciplinary integration. Such integrative interface science can provide new insights which go beyond the sum of what can be learned from its disciplinary components.



## 1. Introduction

The orientation in science towards complex environmental phenomena has raised new challenges for researchers from various fields. These phenomena are typically characterized by dynamic interactions between humans and ecosystems. While historically environmental change has been investigated from the view of single disciplines, its complexity requires interdisciplinary research efforts. We understand interdisciplinary environmental research – after Roy et al. (2013) – as "research that involves scholars from different disciplines collaborating to develop terminology, research approaches, methodologies, or theories that are integrated across multiple disciplines". Such research requires the joint development of appropriate models and interface tools aiming at integrating quantitative and qualitative knowledge (Kelly et al., 2013; Kragt et al., 2013; Kalaugher et al., 2013).

The task of integration is further complicated when addressing societal challenges which call for transformation. Strong societal embedding of research processes becomes important in order to gain a better understanding by integrating different types of knowledge, achieved in professional practice or everyday life (e.g., De Vos et al., 2013), and to foster action-orientation to create transformative potential in the course of the research process (Lang et al., 2012; Hirsch Hadorn et al., 2010). Environmental literacy therefore requires an integrated, holistic view on the environment (Scholz, 2011; Ostrom, 2008). Transdisciplinary research teams consist of both, scientists from different disciplines and representatives of the non-scientific society, and as such enable a co-

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production of knowledge (Jasanoff, 2004; Pohl et al., 2010). The inter- and transdisciplinary dimension of the research addressed in this paper is the process of *communicative*, *social* and *cognitive* integration between scientists and non-scientific actors (Bergmann et al., 2012).

Today, the need for interdisciplinary research is widely acknowledged (e.g., Frodeman et al., 2010; Vasbinder et al., 2010) and transdisciplinary approaches are currently increasing in environmental and sustainability science (Lang et al., 2012; Scholz, 2011). It is recognized that measures suggested by researchers to decision-makers are generally a weak motivation for true sustainable change (Smit and Wandel, 2006). Thus, modes of research that foster the linkage between knowledge production and societal transformation are promising alternatives to more traditional research that focuses only on scientific knowledge production. However, integrative inter- and transdisciplinary research approaches are still far from being consolidated. For many research groups it remains a major challenge, and success in real integration often fails (Roy et al., 2013; Jahn et al., 2012).

Tackling the scientific and societal challenge of climate change – particularly with regard to modelling climatic change impacts – is a paradigmatic example for the need of inter- and transdisciplinary research. When modelling climate change impact phenomena, coupling disciplinary model components via appropriate interface tools is required for passing quantitative and qualitative measures. Such integration is further complicated because the model components are context and research question specific, and requires the consideration of values which are economically, ecologically and socially anchored. Such knowledge produced can directly link to the perceptions, assumptions, challenges and questions which decision or policy makers have. Both, the grasping of the complexity of the phenomenon (Hirsch Hadorn et al., 2008) as well as the impact of modelling results improve when climate change impact modelling is realized in an inter- and transdisciplinary way.

Here, the coupled model has a double role: It is the basis *for* and the aim *of* the integration process. Thus, integration is not just an outcome, but a process in its nature (Jakeman and Letcher, 2003; see also Kelly et al., 2013). Where research on climate change impacts is based on integrated modelling, the joint model development and interface design are hence core elements of integration. Such integration can be regarded as a mutual learning and negotiation process where understanding continuously develops, often unpredictably, and it is highly dependent on how it is organized. One major characteristic of such coupling processes is recursivity: the outcome of a certain model run can stimulate the repetition of the numerical experiment with modified settings. Similarly, in the development of the modelling concept, recursivity can be very important in continuously improving the models quality.

Integration has also become a widely claimed quality in environmental modelling. Kelly et al. (2013) distinguish the five types of integration: (i) integrated treatment of issues, (ii) integration with stakeholders, (iii) integration of disciplines, (iv) integration of processes and (v) integration of scales of consideration. Also Kragt et al. (2013) present challenges of integrated research and modelling of environmental systems, focussing on the modellers role in structuring integrated research projects. They choose the differentiation between technology integration, knowledge integration and team integration. In inter- and transdisciplinary research integration is a major challenge (Stokols et al., 2013; Bammer, 2013; Bergmann et al., 2012; Roy et al., 2013) and has to be addressed in a differentiated manner to be appropriately structured and enabled.

In this article we address the challenge of the integration process in inter- and transdisciplinary modelling, focussing on joint development of interfaces between the model components. We therefore distinguish the three dimensions communicative, social and cognitive, and we show how interface tools can serve both, the integration process itself as well as the integrative modelling. The paper first addresses integration and interface design on a theoretical level, and then shows how it was realized in a specific case study. We discuss how heterogeneous research groups can create a joint language and understanding of diverse perspectives and methodologies that lead to the development of a coupled component model and interface design. Particular attention is paid to the importance of a systematic development of the interfaces to ensure the required consistency and traceability (Giupponi et al., 2013). We then exemplarily outline the application of our coupled component model studying the impacts of climate change on future snow conditions, economy of skiing and regional tourism structure as developed in the two-stage CC-Snow project.[1] With respect to the interface tools of the coupled model – *variables*, *indicators* and *thresholds* – we make an attempt to formalize their functionality in the integration process. We describe how the interface tools support appropriate routing and modification of different types of information across the scientific disciplines in the model. Finally, the potential benefits and challenges of inter- and transdisciplinary research are discussed, with a particular focus on the framework conditions required for integrative research.

## 2. Dimensions and tools for integration

In contrast to disciplinary modelling, where one single person or a homogeneous research team can derive models from theoretical disciplinary backgrounds, the development of models in inter- and transdisciplinary research is a central part of the research process itself (Kelly et al., 2013). The research object is constituted only due to the integration of diverse perspectives and the identification of objectives and goals of the involved parties. The effort of integration varies according to the distance between the knowledge fields, whether they are closely related or widely separated in terms of cultures of cognition and practices. It further depends on the size and the respective heterogeneity of the involved parties. In our case study, the CC-Snow project, we are referring to a research consortium that consisted of several disciplinary research teams from the fields of climatology, hydrology, tourism economy and regional tourism, each having a sub-project leader and research assistants on both the pre- and post-doc level and stakeholders from skiing area management, regional development, tourism management and local administration/policy.

In the following, we outline the different dimensions of integration on a theoretical level. We then show how inter- and transdisciplinary modelling can be initiated, leading to a modelling concept. We will present different integration methods, emphasizing their double role in the integration process and the implementation of the model. As we are referring to a sequential process, we describe and discuss the different aspects in a chronological order from the constitution of the research team to the consolidation and application of the model.

In distinguishing between communicative, social and cognitive dimensions of integration we follow Bergmann et al. (2012). The authors refer to *communicative integration* as the "differentiating and linking of different linguistic expressions and communicative practices" aimed at developing "a common discursive practice in which mutual understanding and communication is possible" (ibid.: 45). This includes the clarification of common terms and, if

[1] CC-Snow: Effects of Climate Change on Future Snow Conditions in Tyrol and Styria (Austrian Climate Research Programme, K09AC0K00038) CC-Snow II: Effects of Future Snow Conditions on Tourism and Economy in Tyrol and Styria (Austrian Climate Research Programme, K10 AC0K00049).