

The ICLIPS Impacts Tool: A Graphical User Interface to Climate Impact Response Functions for Integrated Assessments of Climate Change

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Abstract: This paper presents the ICLIPS Impacts Tool, a graphical user interface that provides access to a large set of climate impact response functions (CIRFs) from the ICLIPS model, an integrated assessment model of climate change. Its reduced-form impact module is comprised of CIRFs that depict the regional sensitivity of selected climate-sensitive impact sectors to changes in important climatic and atmospheric drivers in biophysical terms. The CIRFs were initially developed to enable the incorporation of thresholds for climate impacts in a tolerable windows analysis with the ICLIPS model. However, they are also a valuable source of information in their own right. The ICLIPS Impacts Tool provides convenient access to a large number (ca. 100,000) of impact diagrams for a wide range of impact indicators, geographical regions, and climate projections. The choice of Java as programming language enables the ICLIPS Impacts Tool, which is distributed on a CD-ROM, to run on the most common computer platforms, including Microsoft Windows, Mac OS X, Linux, Solaris, and AIX.

Keywords: Climate change, climate impact response functions, integrated assessment model, ICLIPS, graphical user interface

1 INTRODUCTION

The implementation of the United Nations Framework Convention on Climate Change (UNFCCC) poses many intricate questions to science and international policymaking alike. Integrated assessment models of climate change (IAMs) are scientific tools to assist in this decisionmaking process. They aim at providing a coherent synthesis of important aspects of climate change by combining submodels from diverse scientific disciplines in such a way that the whole set of cause-effect interactions can be evaluated [1].

The distinctive feature of the ICLIPS model, compared to other IAMs, is that it is based on a novel approach to climate-change decisionmaking, the tolerable windows approach (TWA; aka guardrail approach) [2, 3, 4]. The TWA allows a clear-cut separation of normative decisions about the desirability of different policy outcomes on the one hand and the scientific analysis of the relevant components of the Earth system on the other hand. A tolera-

ble windows analysis starts with the explicitly normative specification of minimum requirements for long-term climate policy (so-called guardrails) by the model user in terms of climate impacts, socioeconomic desirability, and international and intergenerational equity. In a second step the ICLIPS model determines the set of climate protection strategies, in terms of emission corridors, that is compatible with these guardrails. The specification of intolerable impacts is rather straightforward for discontinuous changes in the large-scale operation of the climate system such as a potential switch-off of the global thermohaline ocean circulation or a major change in the Asian monsoon system. However, the ICLIPS model can be, and has been, applied to discontinuous as well as continuous climate impacts [3, 5].

The choice of the TWA as the underlying decision-making framework had important consequences for the development of the ICLIPS model. On the one hand, the specification of guardrails in terms of 'intolerable' climate impacts required consideration of

the impacts of a large set of plausible future climate scenarios beyond the level of highly aggregated monetary damage functions, which are applied in most other optimizing IAMs [6]. On the other hand, the determination of *set-valued* solutions (i.e., of climate policies that are compatible with all specified guardrails) by means of solving many dynamical optimization problems made computational efficiency a crucial criterion. In response to these partly contradicting challenges, the ICLIPS model was conceived as a hybrid model where submodels differ in their spatial resolution and temporal characteristics. The core of the ICLIPS IAM combines an efficient global carbon cycle and climate model with a multiregional economic growth model that includes emission rights trading and dynamic carbon mitigation cost functions in an optimizing framework [7]. The ICLIPS core model is supplemented, i.a., by a reduced-form impact model that consists of a large set of sector-specific CIRFs at various spatial aggregation levels [8]. A CIRF depicts the response of a climate-sensitive system to changes in selected indicators of the global climate system. The CIRFs included in the ICLIPS model are derived from extensive simulations with geographically explicit, biophysical impact models.

It is widely recognized that the vulnerability of a system or sector to climate change is a function of the exposure of the system to climate variations, its sensitivity to these variations and its ability to adapt to changing climate conditions [9]. The potential of adaptation to reduce adverse impacts of climate change as well as the capacity of a system to actually perform adaptations are thus important factors in a comprehensive vulnerability analysis. However, the assessment of adaptation, both with a descriptive and with a prescriptive purpose, is a complex task. Adaptation to climate change is specific for each vulnerable system, it depends on the full set of stressors that a system is exposed to and it needs to be integrated with the existing policy context. These features make it very difficult to appropriately address adaptation in a global IAM such as the ICLIPS model.

Human adaptation to long-term climate change may strongly affect the cultural and social foundation of societies by involving, for instance, changes in food patterns, in the seasonal and daily timing of activities, in land use, and in town planning. As a consequence, adaptation assessments typically have a strong normative component. In addition to the scientific problems associated with assessing 'likely' human adaptation, simply assuming that societies will implement certain adaptation measures

would thus be inconsistent with the aim of the TWA to separate the scientific and normative aspects of the climate problem. In a tolerable windows analysis, the main responsibility for evaluating the simulated climate impacts and assessing the ability and willingness of communities to implement adaptations lies with the users of the ICLIPS model. The selection of impact indicators for CIRFs takes into account that this challenge is eased in those cases where climate change is the prime driving force affecting a system and where the potential for adaptation is limited.

The present version of the ICLIPS model contains CIRFs for natural ecosystems, agricultural crops, and water availability [8]. A modified version of the BIOME 1 model that includes the direct effects of enhanced CO₂ levels on the water-use efficiency of plants is used to compute the global distribution of 14 biomes (broad vegetation categories) in equilibrium with a given climate and CO₂ concentration. An adapted version of the FAO crop suitability model determines the suitable area and the potential rain-fed production of the 19 most important food crops worldwide [10]. The global hydrological model WaterGAP 1.1 simulates freshwater availability at the level of river basins [11]. All impact models are equilibrium models with global coverage and a spatial resolution of 0.5 by 0.5 °.

A major problem in linking climate and impact models is the gap in spatial and temporal resolution of these two categories of models. The principal output of the ICLIPS climate model consists of time trajectories for changes in globally averaged near-surface temperature and sea level for a given scenario of greenhouse gas emissions [12]. In contrast, the impact models require geographically explicit data for several climate parameters at monthly or even daily resolution. A scaled scenario approach is applied to bridge this gap [13, 14]. Anomaly patterns for near-surface temperature, precipitation, and cloud cover in each month are extracted from the results of transient simulations with various coupled general circulation models (GCMs) by principal components analysis. These time-invariant patterns are then scaled to the simulated change in global mean temperature and superimposed onto the baseline climatology [15]. As a result, the regional and seasonal variability in the climate change signal simulated by the GCM can be included in the impact analysis even though future climate states are concisely described by a single variable (i.e., the change in global mean temperature). Sub-monthly climate characteristics and interannual climate variability are not considered. Whereas some studies suggest

that the scaled scenario approach works well for temperature but much less so for precipitation [16], recent ensemble experiments with GCMs revealed that *consistent* changes in precipitation patterns are also approximated well [17, 18]. The scaled scenario approach links a CIRF to the anomaly patterns from a specific GCM. The scientific uncertainty about the future climate evolution is partially accounted for in ICLIPS by applying climate projections from different GCMs [15].

All CIRFs presented here use the change in global mean temperature as an input variable. Owing to its strong effect on the water-use efficiency and the photosynthesis rate of plants, atmospheric CO₂ concentration is used as a second input variable in the CIRFs for natural vegetation and crop production. The domain of the CIRFs is chosen so as to be large enough to include the climate–CO₂ trajectories of all SRES emission scenarios until 2100 [19]. Global mean temperature is varied between the average of the 1961–1990 baseline climatology and a maximum value that is about 4.5 K warmer (whereby the exact range depends on the climate sensitivity of the respective GCM). CO₂ concentration ranges from 325 ppm to 1200 ppm. CIRFs are computed by incrementally increasing global mean temperature and CO₂ concentration within these ranges and forcing the impact models with the respective local climate data. The raw model output is further processed to derive various aggregated impact indicators on the level of either individual countries or larger regions (cf. Table 1).

CIRFs are a useful means for the presentation of aggregated simulation results on potential climate impacts and for their inclusion into IAMs. Limitations of the present CIRFs and their application in the ICLIPS model, in addition to not considering human adaptation to climate change, are as follows. First, all impacts are determined in equilibrium with a changed mean climate. In the case of systems with a long memory or a high inertia, such as many ecosystems, the exact timing of a projected change therefore cannot be determined. Second, the ICLIPS climate model, like other reduced-form climate models that mimic GCM results in a deterministic manner, produces smooth climate change projections without any ‘surprises’. These simplifications regarding climate change are related to the limited ability of GCMs to simulate changes in climate variability, including extreme events, and potentially abrupt transitions between multiple equilibria of the climate system [20]. To summarize, the CIRFs presented here should be interpreted as indications of the long-term impacts associated with

a certain change in global mean climate and CO₂ concentration.

2 IMPACT DIAGRAMS IN THE ICLIPS IMPACTS TOOL

The ICLIPS Impacts Tool provides access to a large number of impact diagrams. Section 2.1 gives an overview of the result space of the impact models applied in ICLIPS. Section 2.2 then presents different types of impact diagrams, which combine results across various dimensions of the result space.

2.1 Result space of the impact models

The impact models applied in ICLIPS and the impact indicators derived from their results are based on a number of simplifying assumptions. The result space of these models is nevertheless high-dimensional. The goal of the ICLIPS Impacts Tool is to present these results graphically by combining simulated data points along various dimensions. The relevant dimensions of the result space are as follows:

Impact indicator: The impact indicator of interest (cf. Table 1 for details).

Sub-indicator: Some impact indicators require a sub-category to be specified. The indicator ‘crop yield’, for example, is available for 19 different crop types.

Area coverage: Some impacts have been simulated for the total land surface as well as for spatial subsets that mask out, or focus on, agricultural and protected areas. The indicator ‘crop yield’, for example, is available for the total land area as well as for the currently cultivated area of a region.

Regional grouping, region: The grid-based simulation results from the impact models are first aggregated to the level of individual countries. Owing to restrictions on the manageable data volume in the ICLIPS Impacts Tool and the low reliability of some simulation results at the country level, only selected indicators are reported at the country level. Other indicators are available at the level of larger regions such as biogeographical regions (for indicators on ecosystem changes) and geopolitical regions.

Climate model: The scaled scenario approach links a CIRF to the climate change pat-

Table 1: Indicators for climate impacts on natural vegetation (top), crop production (centre), and water availability (bottom).

Indicator	Explanation
Stable biome area [% of current area]	Percentage of the present range of a specific biome that remains climatically suitable. Newly suitable areas are not taken into account. ¹
Total biome area [% of current area]	Total potential area of a specific biome. Newly suitable areas can compensate for losses within the present range. ¹
Stable forest area [% of current area]	Percentage of the present forest area that remains suitable for forest growth. A change from one forest biome to another one is permitted by this indicator.
Total forest area [% of current area]	Total potential forest area (including newly suitable areas).
Change of present biome [% of area]	Percentage of the specified area where the present biome is no longer viable under altered climate conditions. ²
Crop yield [t/ha]	Rain-fed yield of a specific crop under given climate and soil conditions. ^{1,3}
Suitable area [% of area]	Area where a specific crop can grow (assuming 10% of its maximum yield under optimal climate and soil conditions as the minimum threshold). ^{1,3}
Maximum food energy [Gcal/ha]	Indicator aggregated across all crops. In each grid cell, the crop is chosen that maximizes yield in terms of calorie content. ⁴
Maximum crop performance [% of max. yield]	Indicator aggregated across all crops. In each grid cell, the crop is chosen that has the highest relative performance (measured as the percentage of its maximum yield under optimal climate conditions). ⁴
Weighted crop performance [% of max. yield]	Overall performance of the presently cultivated crops. The yield of each crop in the total cultivated area of a country is weighted with its present share in that country.
Runoff [mm/yr]	Sum of surface runoff and groundwater recharge.

¹This indicator is comprised of various sub-indicators.

²This indicator is available (a) for the total land area, (b) for the land area excluding areas used for agriculture, and (c) for protected areas.

³This indicator is available (a) for the total land area, (b) for the cultivated area, and (c) for the cultivated area whereby in regional aggregations each country is weighted with the crop-specific acreage.

⁴This indicator is available (a) for the total land area and (b) for the cultivated area.

terns from a specific GCM. The present model version uses climate change patterns from ECHAM3-LSG, ECHAM4-OPYC and HadCM2.

Level of climate and CO₂ change: A CIRF represents the dose-response relationship between the magnitude of climate change and the CO₂ concentration as independent variables and the level of the climate impacts as the dependent variable. The dimensions listed so far are sufficient to select a CIRF. The value of the impact indicator for a specific CIRF is determined by the independent variables, i.e., by the level of climate and CO₂ change.

2.2 Types of impact diagrams

Selected results of the impact models are presented in an impact diagram by combining data points along various dimensions of the result space. Different types of impact diagrams, as follows, are used in the ICLIPS Impacts Tool to provide different perspectives on the result space. The examples provided for each diagram type serve mainly an illustrative purpose.

Response surface diagrams depict the response of an impact indicator in a region across the whole domain of the CIRF. These 3-dimensional diagrams give an overview of the sensitivity of the impact indicator to individual and combined changes in its driving vari-

ables. The points on a response surface where the impact indicator equals some pre-defined values can be represented by impact isolines.

Figures 1.a and 1.b, for instance, show the fraction of protected areas worldwide and in Western Europe, respectively, where the climate becomes unsuitable for the current biome based on climate change patterns from ECHAM4 for all combinations of global mean temperature change and CO₂ concentration. A comparison of the two diagrams reveals that the sensitivity of ecosystems to climate change is greater in Western Europe than at the global average whereas the sensitivity to CO₂ is lower in Western Europe.

Impact isoline diagrams show the projection of the impact isolines from a response surface diagram onto the 2-dimensional domain of the CIRF. An isoline separates those climate regimes where the simulated impacts lie below the associated impact level (denoted as the impact guardrail) from those regimes where they lie above. This feature is essential for tolerable windows analyses with the ICLIPS model because observing an impact guardrail becomes equivalent to constraining the evolution of the climate-CO₂ trajectory to the 'tolerable' climate window delimited by the respective impact isoline. The climate evolution simulated for selected emission scenarios can be shown by superimposing the associated time trajectories onto the isoline diagram.

Figures 1.c and 1.d, for instance, show the impact isoline diagrams corresponding to Figures 1.a and 1.b, respectively. The three pointed lines originating in the bottom left corner depict the time trajectories simulated for three IPCC emission scenarios in decadal time steps from 1970 (bottom left corner) to 2100. A comparison of their endpoints in Figure 1.c shows that the SRES A2 emission scenario causes higher global impacts in the year 2100 (between 40 and 50%) than the SRES B2 scenario (between 30 and 40%) and the S450 scenario (between 20 and 30%). When interpreting these numbers, it should be considered that they were determined by an equilibrium biome model. The realization of the simulated changes may therefore be delayed.

Multi-scenario trajectories show the time path of an impact indicator in one region for different emission scenarios. Only those data points

of a CIRF are reported that correspond to climate-CO₂ combinations actually reached by one of the emission scenarios. Whilst information on the differential importance of the two driving variables is lost, the temporal evolution of potential impacts can be clearly seen. These results are analogous to results derived from other impact models in forward mode [21, 22].

Figures 1.e and 1.f, for instance, show the multi-scenario trajectories for the same indicators as in Figures 1.a/c and 1.b/d, respectively.

Multi-regional trajectories show the time path of an impact indicator in different regions for one emission scenario. If the baseline value of an impact indicator differs between different regions, the trajectories are available for the absolute value of the indicator and for relative changes compared to the baseline value.

The trajectories shown in Figures 2.a and 2.b, for instance, depict the fraction of protected area within the 11 world regions considered that would experience a biome change under the SRES A2 emission scenario based on climate change patterns from ECHAM4 and HadCM2, respectively. The simulated impacts vary widely across regions whereby the lowest impacts are consistently simulated for Middle East and North Africa and the highest impacts for Central and Eastern Europe (for more detailed results, cf. Figure 3).

Multi-regional isoline diagrams show the projection of impact isolines onto the domain of the CIRF. In contrast to the impact isoline diagrams described above, the isolines refer to the same impact guardrail for different regions rather than to different impact guardrails for one region. These diagrams as well as the multi-regional trajectories facilitate cross-regional sensitivity analyses of an impact indicator.

Figures 2.c and 2.d, for instance, show isolines that refer to a simulated change of the current biome in 50% of the protected areas of several regions based on climate change patterns from ECHAM4 and HadCM2, respectively. In the year 2100, the 50% guardrail is exceeded in 5 to 6 regions under the SRES A2 scenario, in 3 to 4 regions under the SRES B2 scenario and in 1 to 2 regions under the S450 scenario. The largest difference between the ECHAM4 and HadCM2 climate change patterns is simulated for South Asia. A closer

analysis of the results for that region, shown in Figures 2.e and 2.f, links this deviation to a large difference in the projected precipitation changes for that region.

Multi-category isoline diagrams show isolines for different sub-indicators in one region. They facilitate cross-category analyses of impact indicators in a region.

The isolines shown in Figures 3.a and 3.b, for instance, correspond to those climate-CO₂ states where specific biomes are no longer viable in 50% of their current area in Central and Eastern Europe. The diagrams reveal that most biomes in this region are simulated to be highly sensitive to the climate changes projected by these two GCMs.

Multi-category trajectories show the time path of different sub-indicators within a region for one emission scenario.

Figures 3.c and 3.d, for instance, depict the time trajectories for the stable and total potential area, respectively, of each biome in Central and Eastern Europe under the SRES A2 scenario as a fraction of the total land area. The area suitable for cool mixed forest is simulated to decrease from about 60% to almost nothing whereas the potential area for temperate deciduous forest increases from less than 40% to almost 100%. Figure 3.e shows the normalized version of Figure 3.c, which focuses on the relative changes in the extent of different biomes rather than the absolute changes.

Area balance diagrams are specialized diagrams that depict the gain-loss balance of an area-related indicator across different sub-categories or regions for a specific future climate state, compared to the baseline climate.

Figure 3.f, for instance, shows the simulated share of all biomes in Central and Eastern Europe for baseline climate conditions as well as the climate simulated by ECHAM4 for the year 2100 based on the SRES A2 scenario. The biome share under baseline climate conditions is indicated by points whereas the total and stable area under changed climate conditions are denoted by the upper and lower bars, respectively. Cool mixed forest, which covers almost 60% of the land area under baseline conditions, is simulated to become unsuitable throughout the area with only minor exceptions. In contrast, temperate deciduous forest has the potential to expand its range from less

than 40% to more than 90% of the land surface area.

In the case of CIRFs with only one input variable, e.g., for water availability, response-surface diagrams are represented by two-dimensional dose-response curves, and isolines turn into single points on these curves.

3 THE ICLIPS IMPACTS TOOL

This section introduces the ICLIPS Impacts Tool software. Section 3.1 describes its application and Section 3.2 presents the main technical features.

3.1 Application

Figure 4 shows a screen shot of the ICLIPS Impacts Tool. The central task of the software is the step-by-step selection of an impact diagram from the large database.

Most dimensions of the impact result space (cf. Section 2.1) are represented by a menu in the top panel. The five menus to the left always comprise the dimensions 'impact indicator', 'area coverage', 'regional grouping', and 'climate model' as well as the selection of the 'diagram type'. The choices that are actually available in a menu depend on the selections made in the menus to its left. For instance, the impact indicator determines which area coverages and regional groupings can be chosen. The dimensions represented in the last two menus to the right depend on the selected diagram type (cf. Table 2). Response surface diagrams, for instance, require the selection of a region and, potentially, a sub-indicator. In Figure 4, the menu on the far left is disabled because the impact indicator 'Change of biome' does not comprise sub-indicators.

After a choice has been made from all menus, the selected impact diagram is displayed in the central part of the screen. The bottom panel allows the user to specify one or more emission scenarios, the time trajectories of which can be displayed in isoline diagrams, and to specify graphical properties for the display of impact diagrams. The toolbar to the left allows the user, among other possibilities, to export impact diagrams in different file formats, to print them, and to simultaneously display multiple diagrams. The toolbar to the right gives access to the user help system of the ICLIPS Impacts Tool, which consists of an overview of the program, a guided tour, an illustrated explanation of the choices that

Table 2: Dimensions of the two far right-hand menus depending on the diagram type.

Diagram type	First dimension	Second dimension
Response surface, impact isolines, scenario trajectories	Region	Sub-indicator ¹
Multi-regional isolines	Sub-indicator ¹	Impact guardrail
Multi-regional trajectories	Sub-indicator ¹	Emission scenario
Multi-category isolines	Region	Impact guardrail
Multi-category trajectories, area balance	Region	Emission scenario

¹This dimension is only relevant if the impact indicator requires the selection of a sub-category.

can be made in each menu (such as the different impact indicators and diagram types) and a context-sensitive help for the user interface.

3.2 Technical aspects

The ICLIPS Impacts Tool is written in Java 2. It runs on all platforms for which the Java Runtime Environment (JRE) is available, including Microsoft Windows, Mac OS X, Linux, Solaris, and AIX.

The high dimensionality of the impact result space results in a large set of impact diagrams (about 100,000). These diagrams are available as Encapsulated PostScript (EPS), Graphics Interchange Format (GIF), and Portable Network Graphics (PNG) files. The EPS format combines a small file size with an excellent output quality, including the possibility to scale the diagram without quality loss. However, the Java Virtual Machine only supports the display of raster graphics like GIF and PNG (whereby the latter requires JRE version 1.3 or higher). The ICLIPS Impacts Tool is thus equipped with two different display modes. In basic mode, the raster graphics are displayed directly. In advanced mode, the external image handling tool ImageMagick is called to perform an on-the-fly conversion of the EPS files into a raster format. The program documentation, which is in HTML format, is displayed by the standard browser (on Windows systems) or by the Netscape browser (on Unix systems).

Due to the large number of impact diagrams and the associated data volume, the ICLIPS Impacts Tool is distributed on a CD-ROM that comprises

- the platform-independent Java code,
- all impact diagrams (in compressed EPS and PNG files),
- the program documentation,
- JRE 1.4 for Windows and Linux, and
- ImageMagick for Windows.

The CD-ROM, which can be obtained free of charge from the author of this paper, allows the ICLIPS Impacts Tool to be run in advanced mode on 32-bit Windows and Linux platforms. On Mac OS X, which comprises the JRE, it runs in basic mode only unless ImageMagick and Ghostscript are installed. On other platforms, such as Solaris and AIX, the JRE needs to be installed for running the ICLIPS Impacts Tool. A web browser is required to view the documentation. All other third-party software mentioned before is available for free from the respective developers.

4 SUMMARY AND OUTLOOK

This paper presented the ICLIPS Impacts Tool, a software tool that makes the comprehensive set of climate impact response functions (CIRFs) developed for the ICLIPS integrated assessment model available to a wider community by means of a convenient graphical user interface. The CIRFs result from a large set of simulations on the impacts of changes in mean climate and atmospheric CO₂ concentration, using maximum information from complex climate models. They bridge the gap between changes in globally averaged climate parameters and selected impacts at the global, regional, and national level.

The ICLIPS Impacts Tool provides a structured and transparent way to access the aggregated simulation results. It may be used to obtain an overview about potential climate impacts as simulated by biophysical impact models and to derive ‘tolerable’ climate windows corresponding to a certain threshold for climate impacts. It also supports sensitivity analyses across impact indicators, geographical regions, emission scenarios, and climate projections from different GCMs. In so doing, the ICLIPS Impacts Tool helps to enhance the knowledge about potential climate impacts, including their regional and sectoral diversity and some aspects of uncertainty.

The ICLIPS Impacts Tool is distributed on a CD-ROM that runs on most computer platforms. An important component of the ICLIPS integrated assessment model is now available to the public. The object-oriented design of the ICLIPS Impacts Tool provides maximum flexibility to include new results as they become available.

The limitations of the ICLIPS Impacts Tool are two-fold. Firstly, the impact models applied to determine the CIRFs ignore some important factors, for instance interannual climate variability, socio-economic factors affecting the vulnerable system and the potential of planned adaptation. Secondly, the computer tool covers only the impacts part of the ICLIPS integrated assessment model. While the inclusion of additional features into the ICLIPS Impacts Tool appears desirable at first sight, it would certainly increase its complexity. Potential users might no longer be able to manage the program and understand all assumptions that exert influence on the model results. The ICLIPS Impacts Tool thus represents a compromise between flexibility in its use, realism in the representation of the relevant system components, and comprehensibility of its results.

Further developments of the ICLIPS Impacts Tool may either extend the database of CIRFs or the functionality of the software. Extensions of the CIRF database would require the use of DVDs as distribution medium because the storage capacity of CD-ROMs is already fully utilized by the present database. The most important additional functionality appears to be the possibility to export the numerical simulation results represented in the impact diagrams, either as raw data or by using parameterized approximations of CIRFs and impact isolines.

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ACKNOWLEDGEMENTS

Financial support for the ICLIPS project was provided by the German Federal Ministry of Education and Research (BMBF) under project number 01 LK 9605/0.

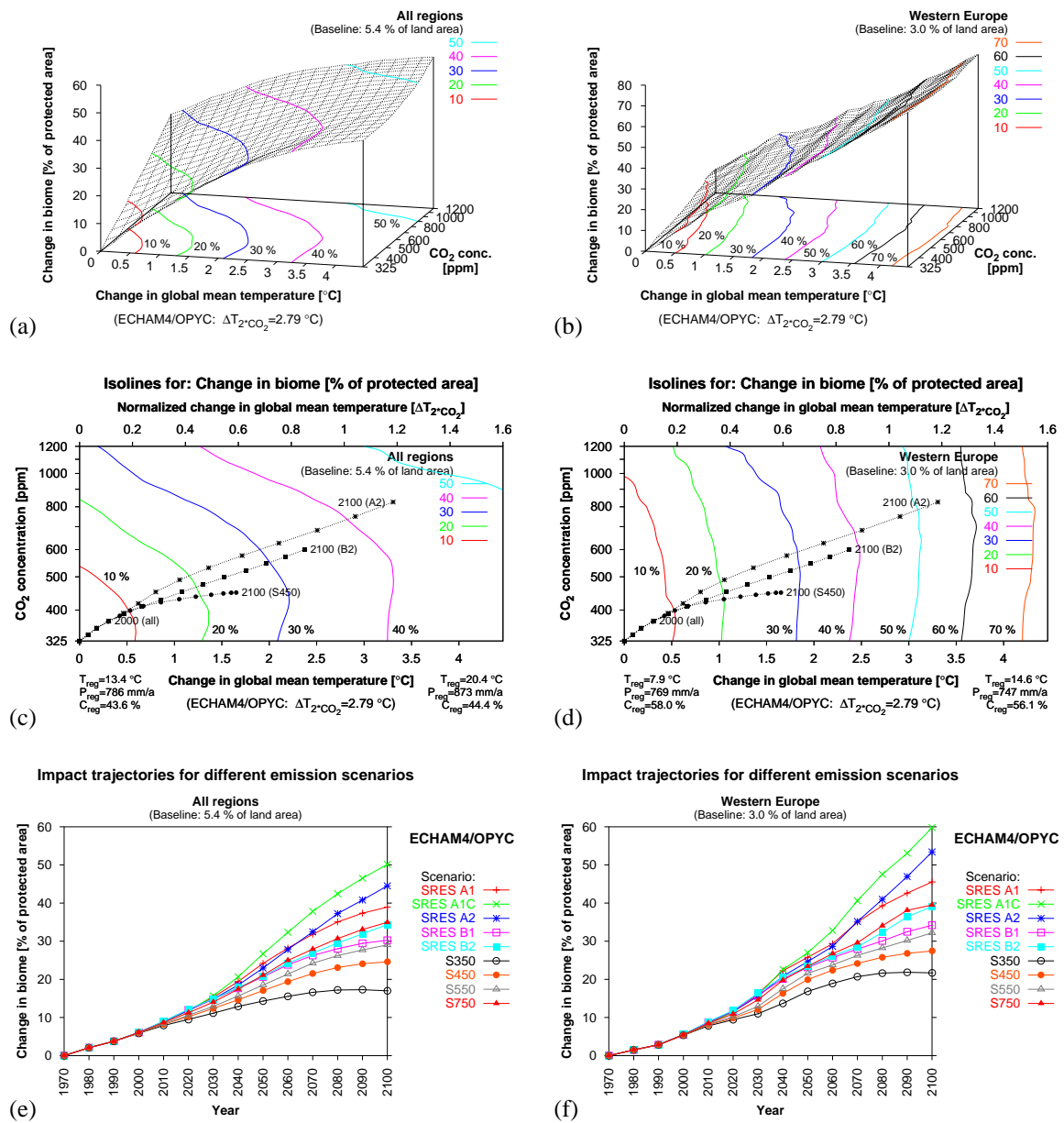
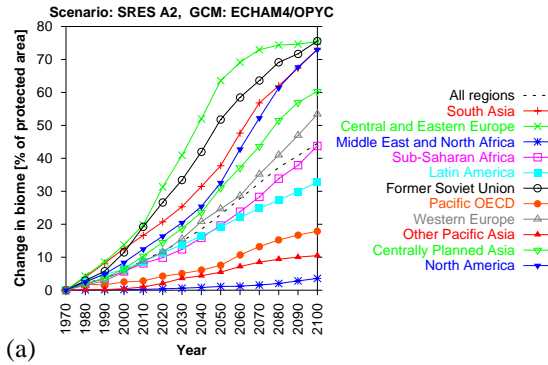


Figure 1: Different types of impact diagrams. (a), (b): response surface diagrams; (c), (d): impact isoline diagrams; (e), (f): multi-scenario trajectories.

Impact trajectories for one emission scenario



Impact trajectories for one emission scenario

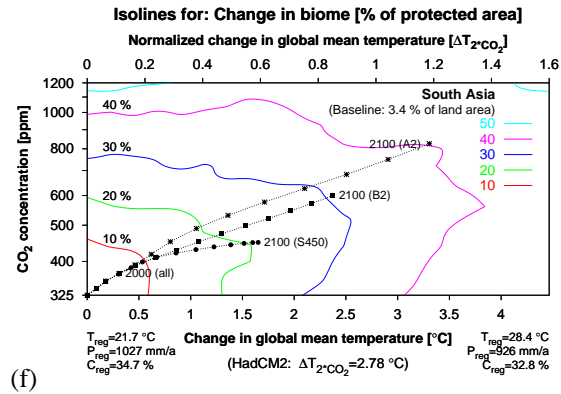
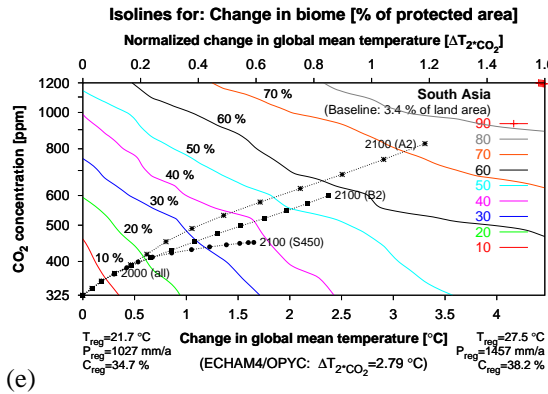
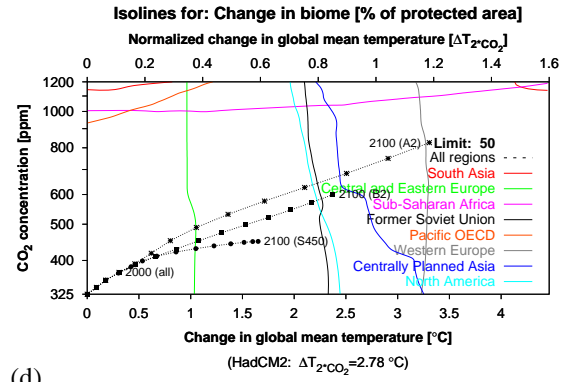
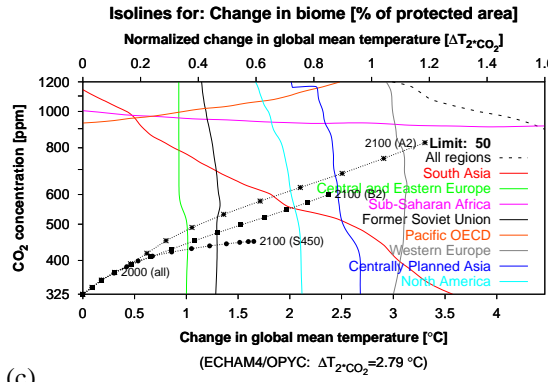
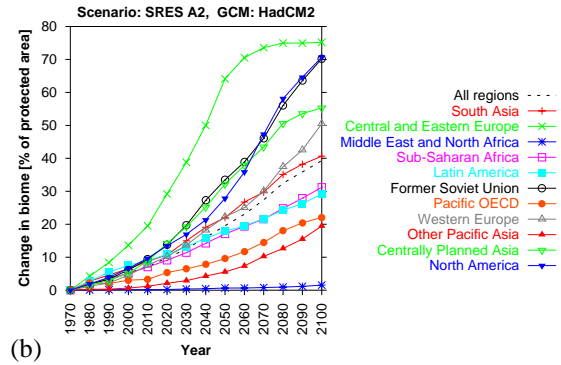


Figure 2: Different types of impact diagrams (ctd.). (a), (b): multi-regional trajectories; (c), (d): multi-regional isoline diagrams; (e), (f): impact isoline diagrams.

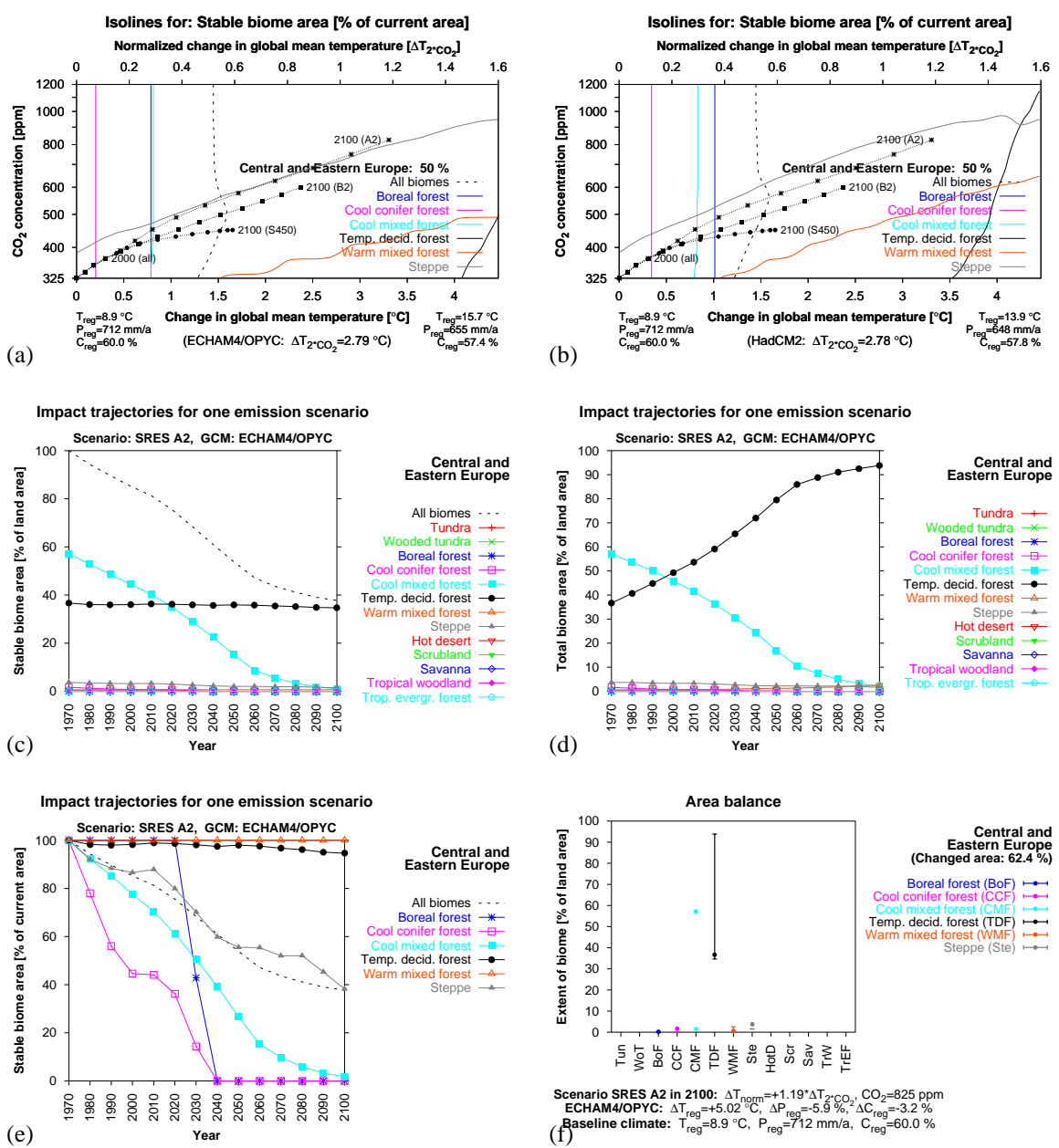


Figure 3: Different types of impact diagrams (ctd.). (a), (b): multi-category isoline diagrams; (c), (d): multi-category trajectories (absolute); (e): multi-category trajectories (normalized); (f): area balance diagram.

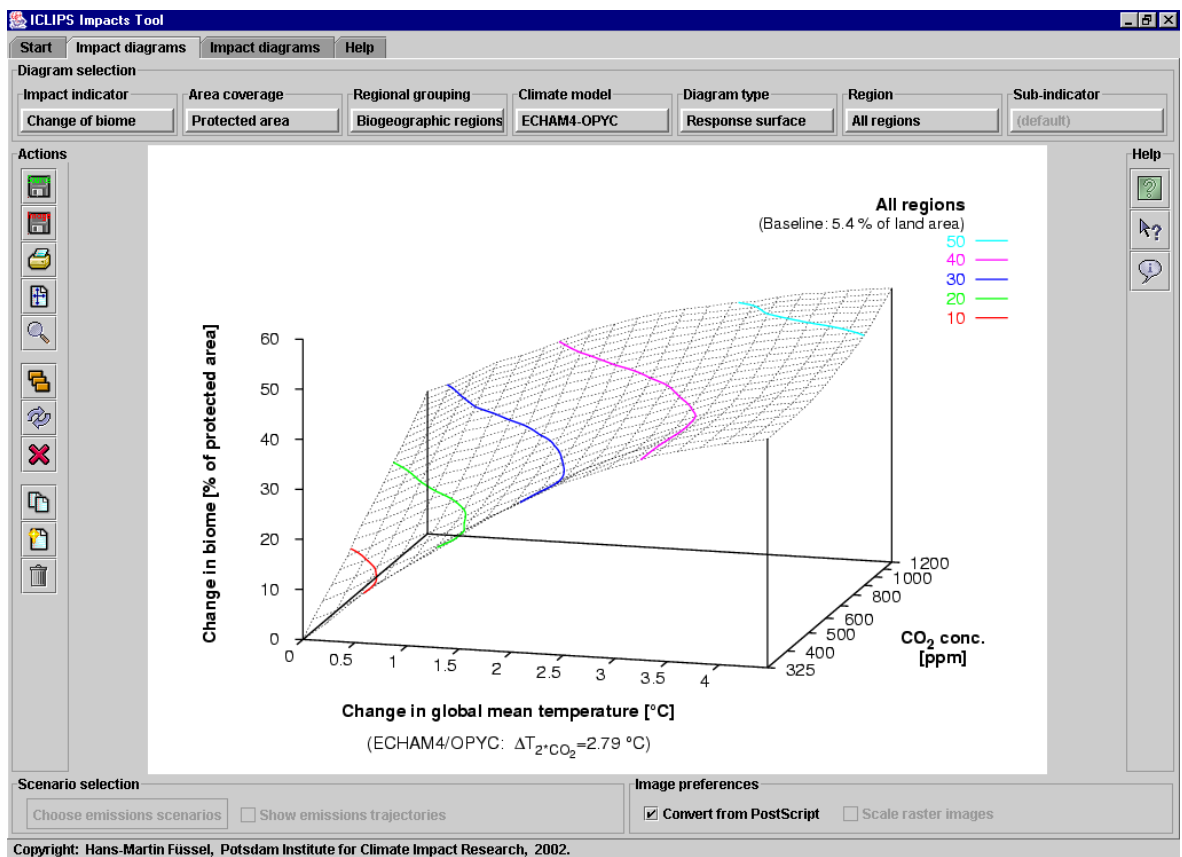


Figure 4: Screen shot of the ICLIPS Impacts Tool showing a response surface diagram.