CLIME -DSS
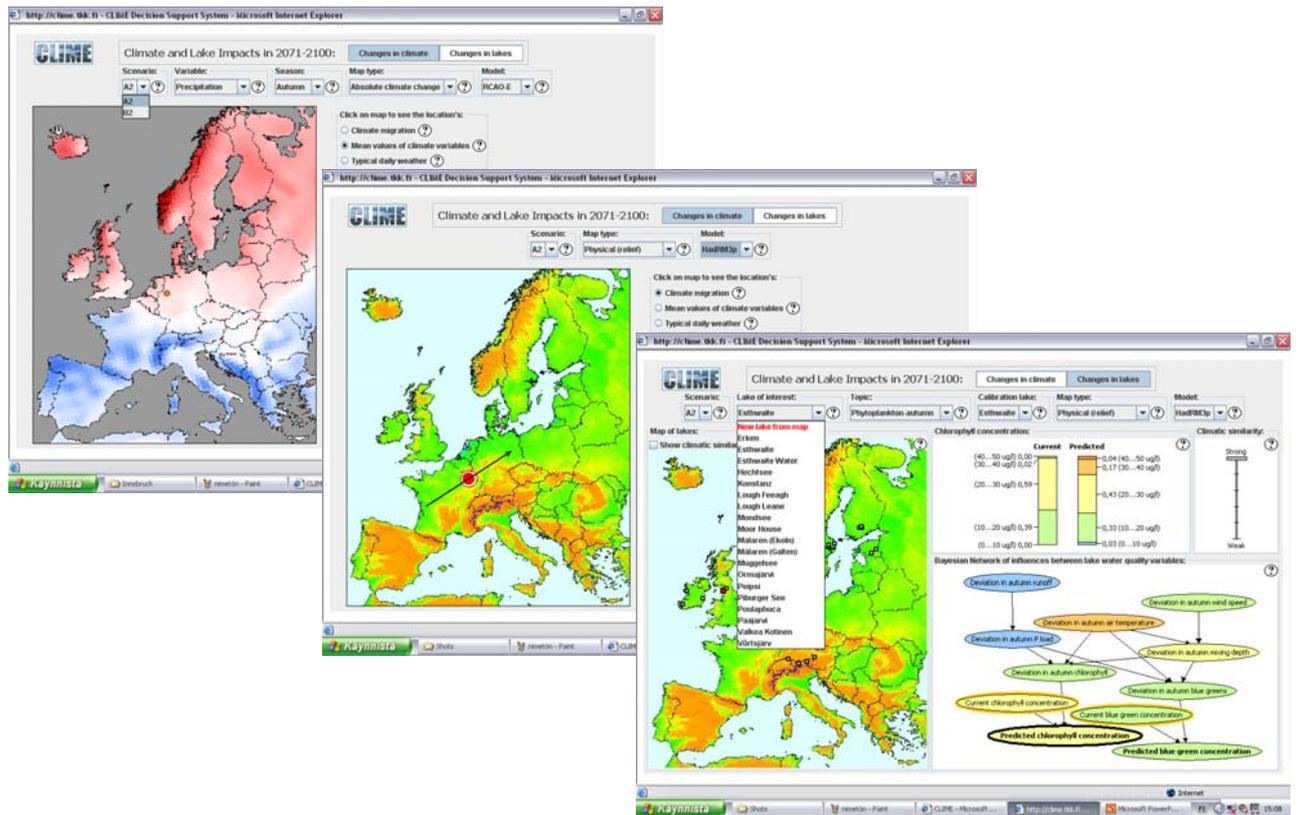
USER MANUAL

HELSINKI UNIVERSITY OF TECHNOLOGY

What is the CLIME-DSS?

Objective

The objective of the CLIME Decision Support System (CLIME-DSS) is to summarise and illustrate the main results of the CLIME project in such a form, that they are easily accessible and comprehensible to interest groups both within and outside of the research community. The CLIME-DSS presents information about projected changes in the climate of Europe, and in lake characteristics driven by the changing climate.

Development of the CLIME-DSS had the following goals:

1) capability of illustrating predicted changes in major climate characteristics across Europe
2) capability of illustrating main effects of the projected climate change on key variables characterising lakes across Europe
3) intuitive usability also for persons that are not experts in meteorological and limnological sciences
4) usability over the Internet
5) extensibility, i.e. capability to readily incorporate a new decision support issue

Brief description of the methodology behind the CLIME-DSS

The climatic projections used in the CLIME-DSS are based on three regional climate models (RCM). More details are given in (Samuelsson, 2004). The RCM results include simulated daily time series of meteorological and hydrological variables for two time periods: 1961 – 1990 (control) and 2071 – 2100 (future). The levels of greenhouse gas emissions are different in the control and future periods. Within each period the emissions, however, remain at the same level. The CLIME-DSS visualises the projected difference in climate between these two periods.

In the CLIME-DSS the impact of climate change on lake characteristics is described using probabilistic Bayesian networks. A Bayesian network can be presented as a directed, acyclic graph, which consists of nodes representing variables, and arcs representing dependencies between the variables (e.g. Pearl, 1988). All variables in a Bayesian network are described as probability distributions, and dependences between the variables are described as conditional probabilities between a dependent node and its parent nodes. A parent node refers to an explanatory variable that is directly connected to the dependent variable. In the CLIME-DSS, variables in the Bayesian networks are discrete, and the conditional probabilities between a set of variables are presented in the form of conditional probability tables (CPT).

Structures of Bayesian networks, i.e. selection of variables and the causal relationships amongst them, are identified on the basis of expert knowledge and the structure of environmental simulation models used in CLIME. The values for the CPTs are derived using either simulation model applications or empirical equations.

Instead of using absolute values in the Bayesian networks of the CLIME-DSS, deviations from prescribed reference levels are adopted to describe the climate change impact on lake characteristics. In other words, variables in the Bayesian networks describe how annual/seasonal values deviate from the reference level. The reference level is the long-term mean value of a variable for the control period from 1961 to 1990. Deviations are used as it is assumed that regionalisation of results based on deviations is more robust than regionalisation of results using absolute values. Regionalisation means here application of the CLIME-DSS to other European locations outside of those sites from which there were data available in CLIME. The CLIME-DSS, however, supports converting the projected deviations into future values. The user may select the current level of an objective variable, and the system adds the deviation distribution on top of the current level to produce the projected distribution of the future level.

Technical requirements

CLIME-DSS is a Java applet and therefore Java (not same as Javascript) has to be enabled in the Internet browser options. The applet requires Java Runtime Environment 1.5. JRE 5.0 can be downloaded free of charge from java.sun.com.

CLIME-DSS help system

Whenever there is a question mark symbol ⓘ in the CLIME-DSS panel, pointing to the question mark displays information on the topic relevant to the context.

Two sides of the CLIME-DSS

When the user opens the CLIME-DSS a load indicator appears while the CLIME-DSS retrieves data from the server.

The CLIME-DSS is divided into two main panels:

1) *Changes in climate*

   and

2) *Changes in lakes*

The user can switch between these two panels by clicking the two tabs that are labelled *Changes in climate* and *Changes in lakes* and are located at the top of the page (Figure 1).
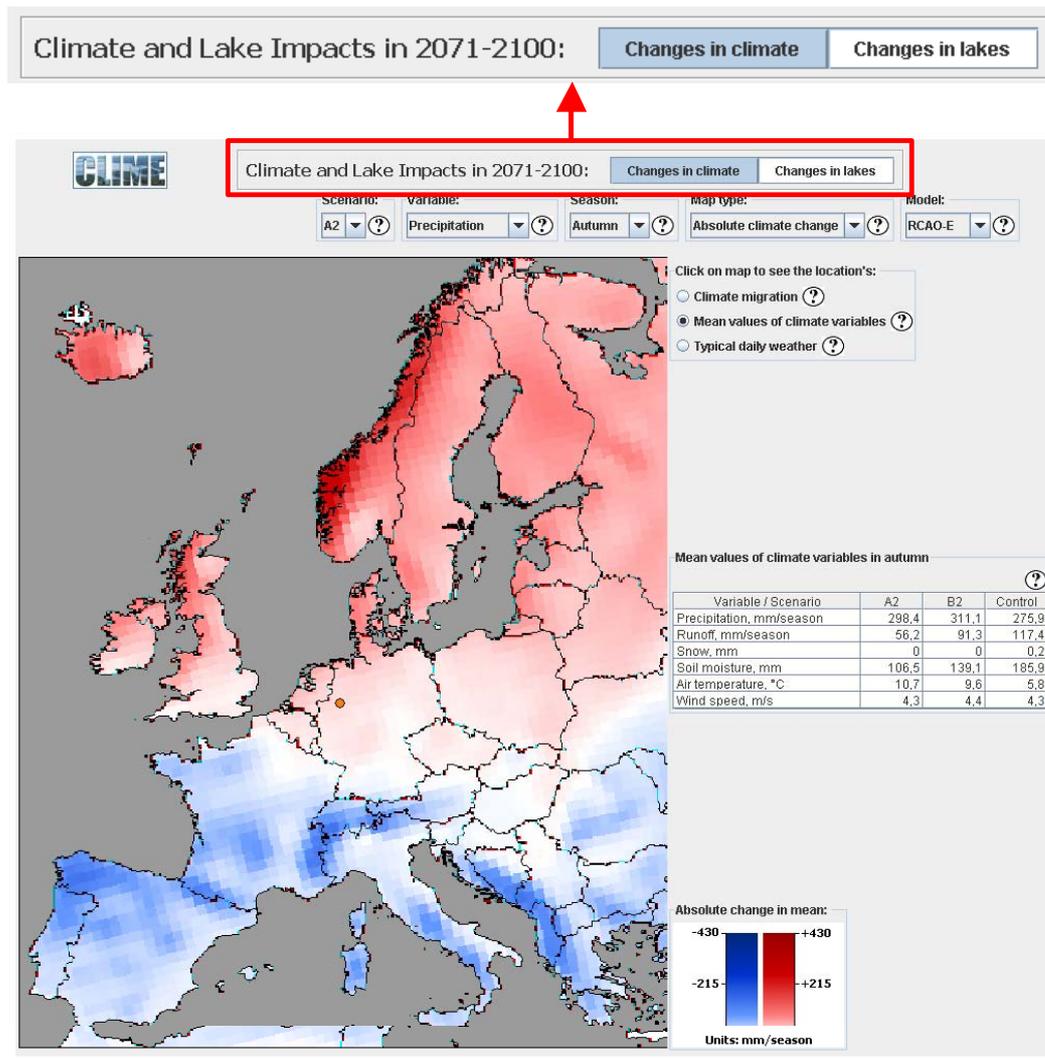
Figure 1. Selecting the *Changes in climate* panel or the *Changes in lakes* panel.

Changes in climate

This panel provides tools for studying how the climate is projected to change in Europe from the control period (1960 to 1990) to the future period (2071 to 2100). The projected climate change is presented in terms of:

1. Changes in mean values of a set of climate variables. The change is computed as the difference between the 30 year mean values for control and future periods.
2. Climate migration. This tool displays where in Europe the current climate most resembles the future climate in the selected location.
3. Changes in typical daily weather. As opposed to single variables, daily weather considers several variables at time.

Changes in mean values

In order to study projected changes in mean values of climate variables, the *Mean values of climate variables* radio button must be selected (Figure 2b).

The system stores over 300 climate change maps, which display results for different combinations of:

1. Emission scenarios according to the Intergovernmental Panel of Climate Change
   - o A2 and B2.
   - o *Scenario* drop-down list (Figure 2a)
2. Variables
   - o Precipitation, runoff, snow, soil moisture, air temperature, wind speed.
   - o *Variable* drop-down list (Figure 2a)
3. Season
   - o Autumn, spring, summer, winter
   - o *Season* drop-down list (Figure 2a)
4. Relative or absolute change
   - o Some variables allow to study both relative and absolute changes.
   - o *Map type* drop-down list (Figure 2a)
5. Regional climate model
   - o 3 different climate models labelled as HadRM3p, RCAO-E and RCAO-H, for more information see Samuelsson (2004).
   - o *Model* drop-down list (Figure 2a)

The user selects from drop-down lists (Figure 2a) which climate change map is displayed. Pointing to the question marks next to the drop-down lists displays information on the selected option.
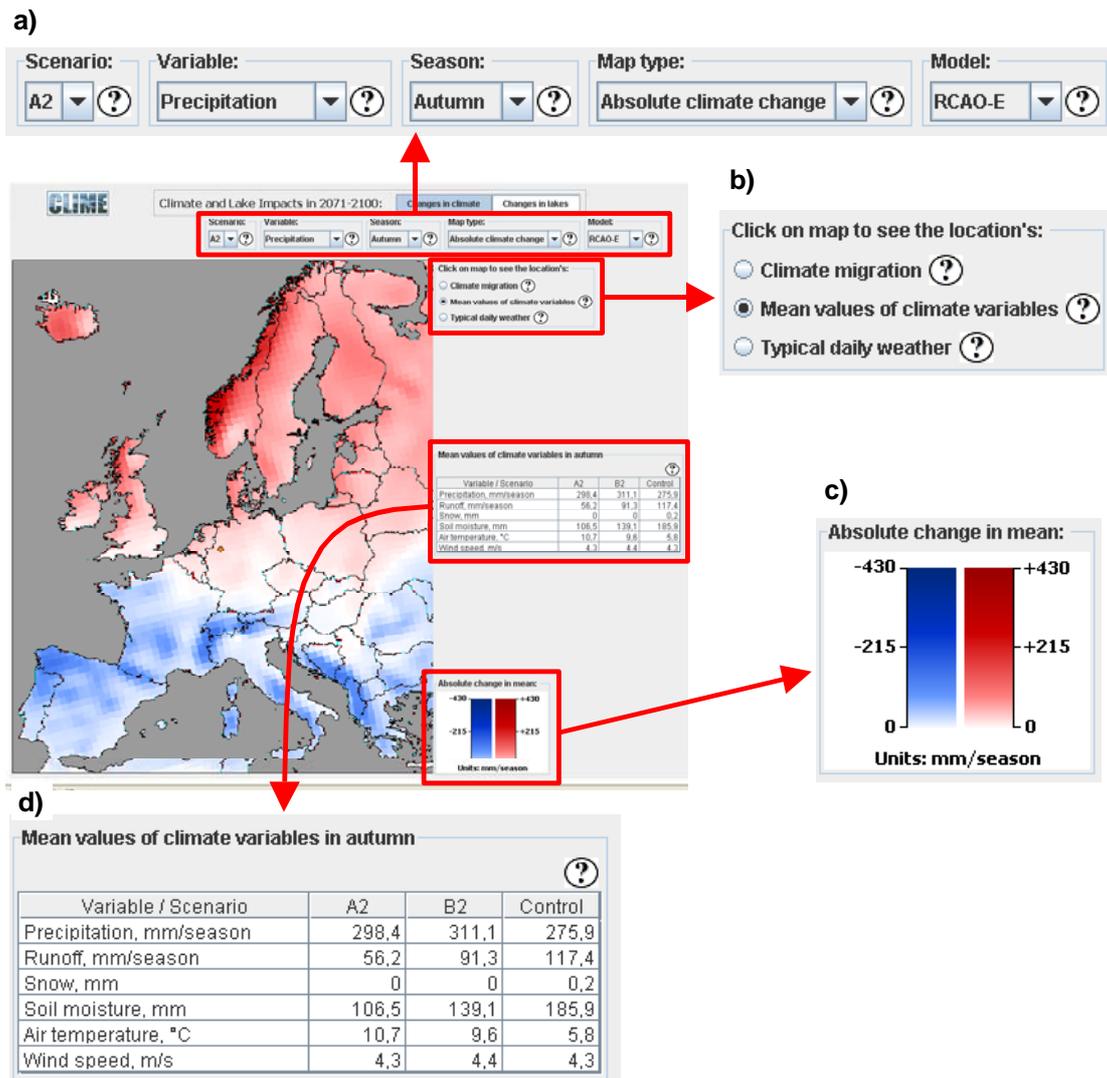
Figure 2. Selecting the *Scenario*, *Variable*, *Season*, *Map type* (absolute or relative change), and *Model* from drop-down lists (a); selecting *Mean values of climate variables* radio button (b); legend for the map (c); and table of climate variables for the selected location (d).

There is a legend in bottom right corner that explains what the colours in the climate change map mean (Figure 2c). In general, blue means always decrease, red increase, and white that there is no change between the control and future periods. In addition to looking at the spatial distribution of the projected change on the map, the user can click to a location on the map (orange dot) for a more detailed table showing the seasonal values of climatic variables for the control period as well as for the future period under both A2 and B2 scenarios (Figure 2d).

Climate migration

Selecting *Climate migration* radio button activates a mode where the user can click on a map and identify the place in Europe where the current climate most resembles the future climate at the clicked location (Figure 3a). In other words, the climate migration arrow indicates from where the climate is going to "migrate" to the selected location. When the user selects a location by clicking on the map, an arrow with a

circle appears (Figure 3b). The head of the arrow points at the selected location, and the tail of the arrow indicates the location where the current climate most resembles the future climate in the selected location. Strength of resemblance (similarity) is illustrated with a circle, where the diameter of the red circle within the white circle increases with an increasing resemblance.
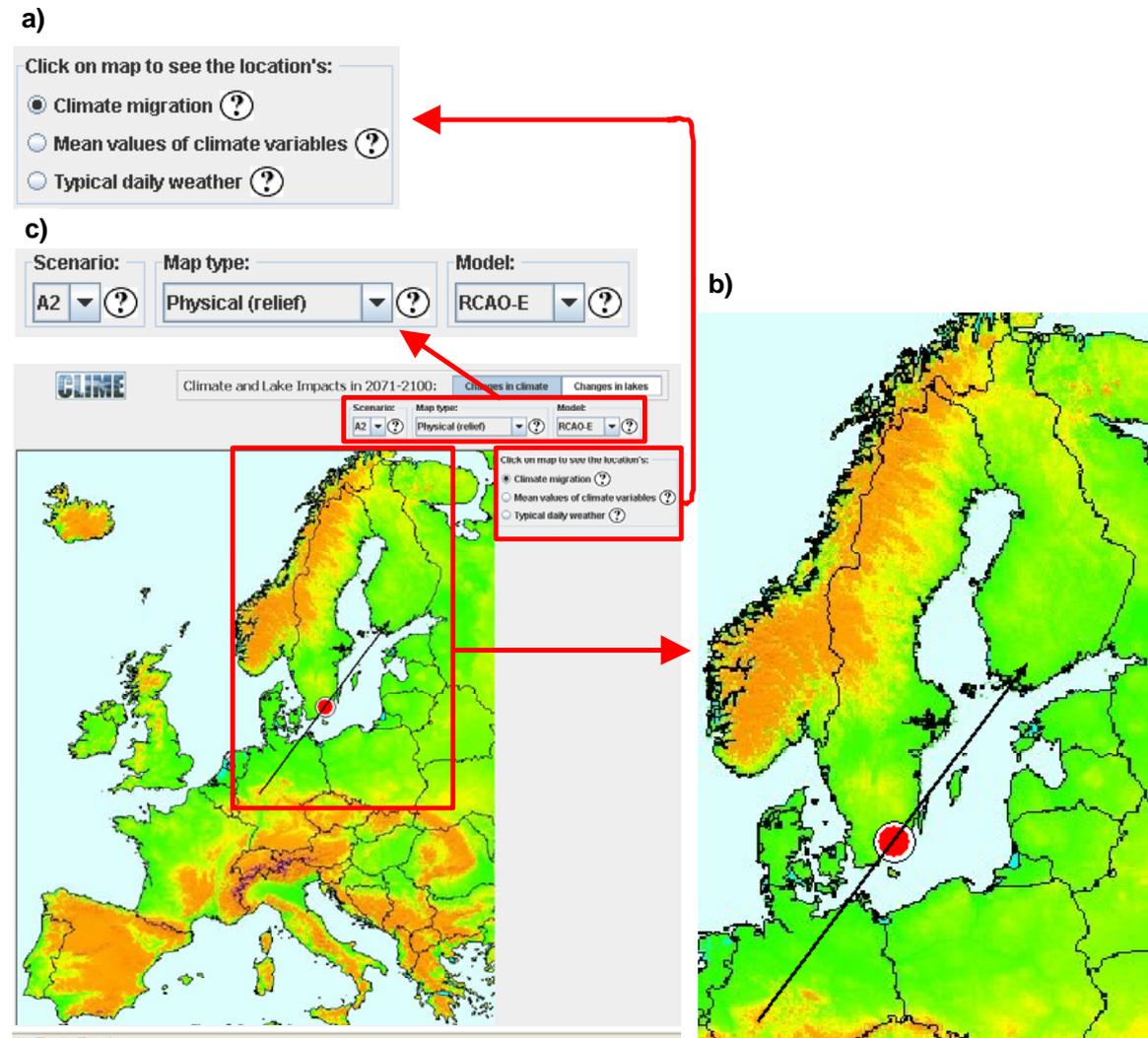

Figure 3. Selecting *Climate migration* radio button (a); climate migration arrow on the map (b); and selecting scenario, map type, model (c).

The user can select the scenario, map type, and climate model from a drop-down list (Figure 3c). Different map types include: relief, land cover, and location of peat lands and lakes (the size of lakes is exaggerated for better visibility).

Changes in typical daily weather

Clicking the *Typical daily weather* radio button (Figure 4a) changes the table of climate variables to a table of typical daily weather (Figure 4b). In contrast to studying climate variables separately, the typical daily weather considers several climate variables at one time. Weather types have been determined using discrete

classes of the following variables: precipitation, runoff, snow water equivalent, soil moisture, air temperature, and wind speed. Discretisation intervals are shown when the user points to question marks in the last column of the table.
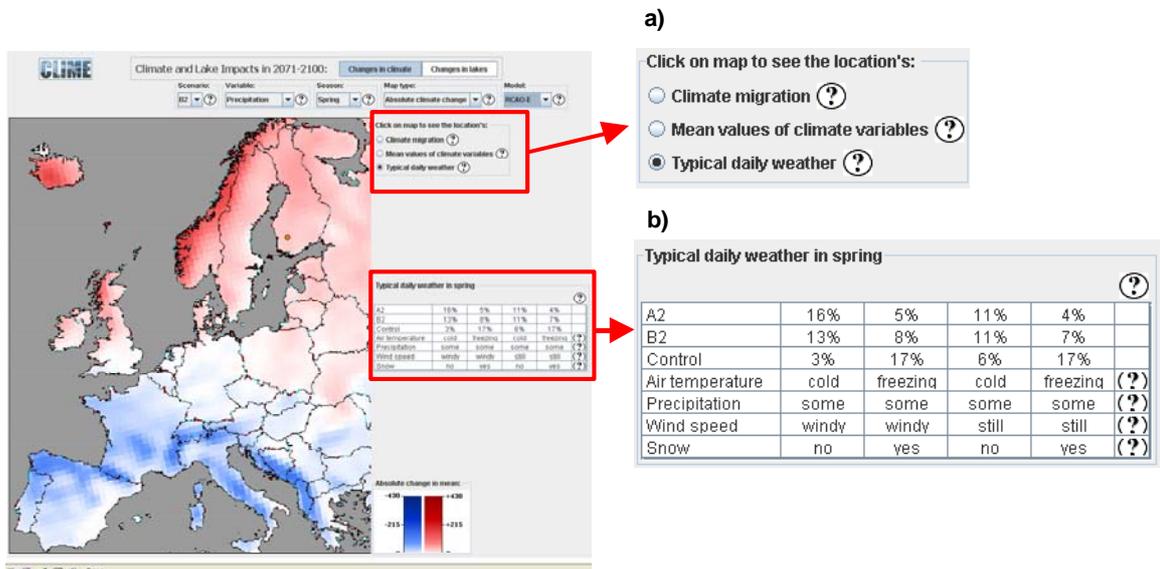

Figure 4. Selecting *Typical daily weather* radio button (a); and table of typical daily weathers for the selected location (b).

In brief, the only difference between *Changes in mean values* mode and *Typical daily weather* is that the table showing the table of climate variables is replaced with the table of typical daily weathers, which shows the four most common daily weather types for the selected location and the selected season. The percentage values in the first three rows give the frequency of the four daily weather types under control and future scenarios.

Changes in lakes

General instructions

This panel allows the user to analyse the effects of climate change on the key lake characteristics. Those lake characteristics that are available for the analysis are listed in the *Topic* drop-down list (Figure 5 a) which is located on top of the map of Europe. In addition to the topic, the user can select the *Scenario*, the *Map type*, and the climate *Model* from drop-down lists (Figure 5a) similar to the *Changes in climate* panel. Also, there is a *Lake of interest* drop-down list which includes all lakes that were studied in CLIME (Figure 5a). The user can select the lake of interest either from this list or by clicking a CLIME lake location on the map. All CLIME lake locations are shown as white squares on the map, and the selected site is shown as a red square. For studying a location that is not included in the CLIME sites the user can select in the *Lake of interest* drop-down list the first entry labelled as *New lake from map*. When *New lake from map* is active, the user can click any location on the map for analysis. The *Calibration lake* drop-down list (Figure 5a) allows the user to pick that lake (or

catchment of the lake) whose data have been used in identifying values for the CPTs in the Bayesian network.

For each topic, the analysis is based on an application of a Bayesian network, whose graphical representation is shown in the lower right corner of the panel (Figure 5b). Variables are presented as ovals and the causal relationships between them as arrows. The user can select a variable by clicking the ovals.

Above the Bayesian network figure there is graph showing the probability distribution of the selected variable (Figure 5c). Each distribution is discretised into five classes. Both the class ranges (in parentheses) and the probability value are given next to each class. Each class has a different colour, and these colours are also used in the Bayesian network figure to denote the mode class (i.e. the class having the highest probability value). If a node in the Bayesian network figure shows as white, all five classes have equal probability values.

Similar to the *Changes in climate* panel the user can select the scenario, map type, and climate model from drop-down lists (Figure 5a). Also, there is a *Lake of interest* drop-down list which includes all lakes that were studied in CLIME (Figure 5a). The user can select the lake of interest either from this list or interactively from the map. All CLIME sites are shown as white squares on the map, and the selected site is shown as a red square. For selecting a location that is not included in the CLIME sites the user can select in the *Lake of interest* drop-down list the first entry labelled as *New lake from map*. When *New lake from map* is active, the user can pick any location on the map for analysis. The *Calibration lake* drop-down list (Figure 5a) allows the user to pick that lake whose data have been used in parameterising the Bayesian network.
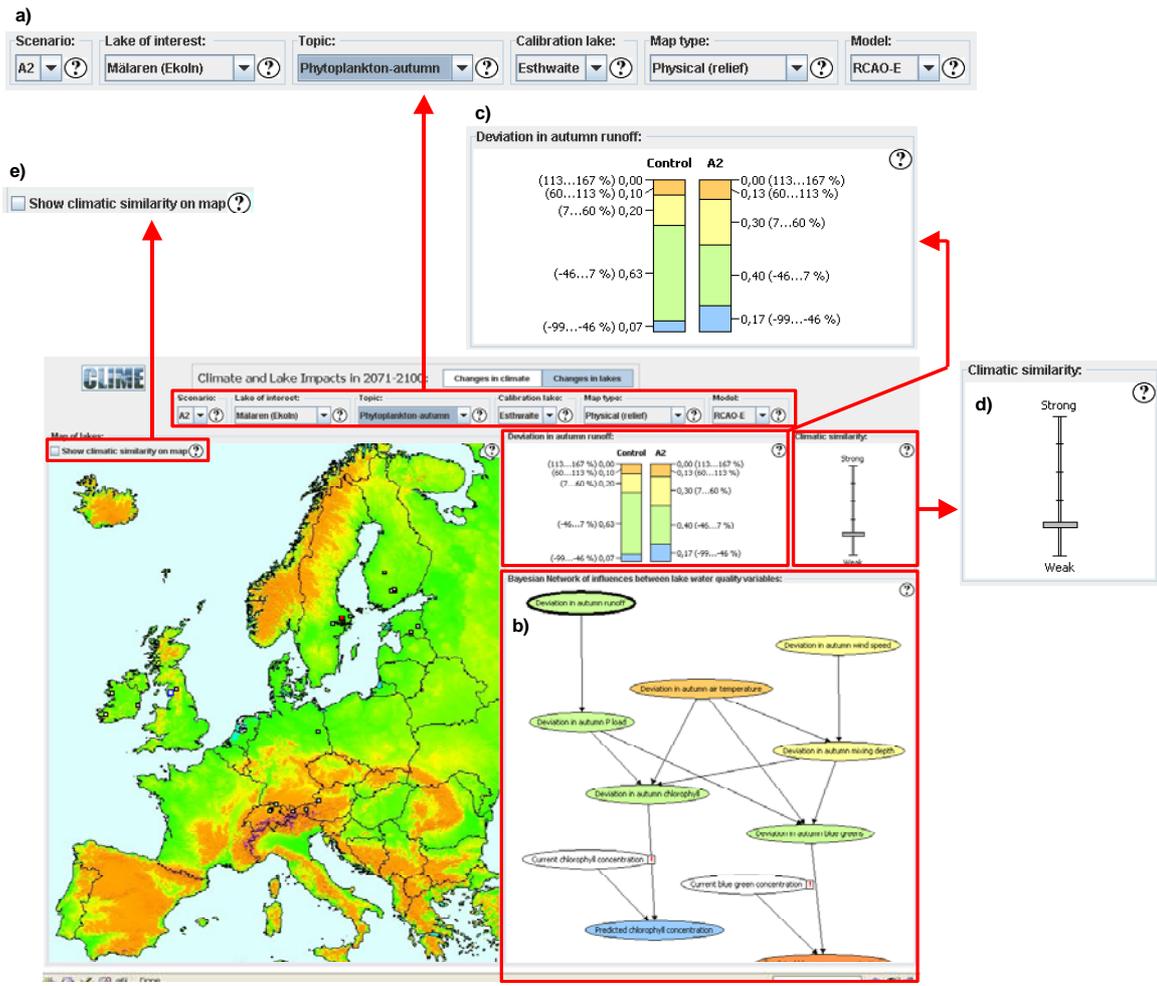
Figure 5. *Changes in lakes* panel. *Scenario*, *Lake of Interest*, *Topic*, *Calibration lake*, *Map type*, and *Model* drop-down lists (a); Bayesian network figure (b); probability distribution of the selected variable (c); climatic similarity indicator (d); and *Show climatic similarity on map* check box (e).

The CLIME-DSS provides help in assessing how similar the climate is at the calibration site and at the site of interest. The idea is that the uncertainty in the results increases when the difference in climate between the calibration site and the site of interest increases. There is a climatic similarity indicator above the Bayesian network figure (Figure 5d). Moreover, by checking the *Show climatic similarity* check box above the map (Figure 5e) the user can apply a mask that paints those regions white that are climatically far away from the calibration site.

Assessing future levels

While the DSS provides tools to assess the distribution of all variables in the Bayesian networks, the most common way to use it is to select the current level of the target variable and then study the distribution of the projected future level. At the bottom of each network there are nodes representing current levels of the target variables. By selecting a *Current* level node, and then clicking on any of the five classes the user can fix the current level to that class. In addition to selecting a single class to

represent the current level, the user can drag the borders between the classes to specify a distribution for the current level. When the mouse cursor is placed on the border between two classes the cursor changes into a double arrow to indicate that the class height can be adjusted. Also, to enable an easier assessment of future levels using different current level scenarios, the same functionality of adjusting the current levels is available when a node representing the *Predicted* level is selected at the very bottom of the Bayesian network figure.

Examples of use

Changes in climate

Q1: How is precipitation projected to change in the winter season in Europe from the control period (1960 to 1990) to the future period (2071 to 2100)?

Answer:
Click first *Changes in climate* button (Figure 1) if the 'Changes in climate' panel is not already active. Also, make sure that either *Mean values of climate variables* or *Typical daily weather* radio button is active (Figure 2b).

Select 'Precipitation' from the *Variable* drop-down list and 'Winter' from the *Season* drop-down list. If you want to see the projected change in millimetres select *Absolute climate change*, and should you wish to assess the change in percentage select *Relative climate change* from *Map type* drop-down list (Figure 2a).

The map shows in red and blue colours the spatial distribution of the projected change in precipitation in Europe. Red colour denotes increase, and blue decrease. The magnitude of the change is represented by the shade of the colour. The legend is shown at the bottom on the right side of the map.

Selecting either *A2* or *B2* from the *Scenario* drop-down list allows you to assess the projected precipitation change either under more (A2) or less (B2) severe atmospheric emission scenarios (Figure 2a). Please see, e.g., Samuelsson (2004) for more information on the emission scenarios.

Changing the regional climate model on whose results the projections are based from the *Model* drop-down list (Figure 2a) allows you to study how consistent the three climate models used in CLIME project are in their projections for different parts of Europe. For example, it can be concluded that all model show an increase in precipitation for England, Ireland, Sweden, Finland, and Denmark. But for example, in case of Norwegian west coast RCAO-E projects an increase in winter precipitation while RCAO-H and HadRM3p suggest a decrease.

To obtain more detailed information on a specific location you can click on the map and look at the table showing either mean values of selected meteorological variables (*Mean values of climate variables* radio button selected, Figure 2b) or typical daily

weather (*Typical daily weather* radio button selected, Figure 2b). See previous sections for more details on what is meant with the typical daily weather. Note that the mean values for meteorological values are results of a simulation model which uses 50 x 50 km^2 grid cells in the computation. Due to local controls on climate, it is quite possible that in the control period (representing current climate) you obtain results that seem to be different to your knowledge of a certain location within that grid cell. It is recommended to pay more attention to the projected change in climate than to the absolute values of the climate variables in the control and future periods.

Q2: Where in Europe the current climate most resembles the future climate in Stockholm under scenario B2?

Answer:
Click first *Changes in climate* button (Figure 1) if the *Changes in climate* panel is not already active. Also, make sure that you have selected the *Climate migration* radio button (Figure 3a).

Click location of Stockholm on the map and you see an arrow whose head is at Stockholm. The tail of the arrow indicates where in Europe the current climate is most similar to the future climate in Stockholm. Strength of resemblance (similarity) is illustrated with a circle, where the diameter of the red circle within the white circle increases with an increasing resemblance.

From the *Scenario* drop-down list (Figure 3c) you can change the emission scenario to study its effect on the location of the closest resemblance. Moreover, the regional climate model used for climate simulations can be used from the *Model* drop-down list (Figure 3c). In order to assess how sensitive the climate migration result is on assumptions used in the analysis, it is recommended to test different climate models and to click a couple of times in the neighbourhood of the study location (in this case Stockholm). Sometimes the tail of the arrow jumps a substantial distance as a result of changing the climate model, or when the study location is changed only little.

Changes in lakes

Q3: What is the projected future DOC concentration distribution

   a) in Lough Feeagh in western Ireland when the current (long term mean) level is between 5 and 10 mgC/l?
   b) in Poulaphuca in eastern Ireland when the current (long term mean) level is between 5 and 10 mgC/l?
   c) in a lake in southern Sweden when the current (long term mean) level is assumed to be between 10 and 15 mgC/l?

Answer:
Click first *Changes in lakes* button (Figure 1) if the *Changes in lakes* panel is not already active. Select *Water colour (DOC)* from the *Topic* drop-down list (Figure 5a). Selecting either *A2* or *B2* from the *Scenario* drop-down list (Figure 5a) allows you to assess the projected precipitation change either under more (A2) or less (B2) severe atmospheric emission scenarios. The *Model* drop-down list (Figure 5a) provides the option to change the regional climate model which has been used for generating the results – should you wish to assess the sensitivity of the results on the choice of the climate model. Also, you can select the background map type from the *Map type* drop-down list (Figure 5a). You can choose between three different map types: *Physical (relief)*, *Land cover*, and *Peatlands and lakes*.

a)
Select Lough Feeagh as the lake of interest. There are two alternative ways for doing that. You can either select Lough Feeagh from the *Lake of interest* drop-down list (Figure 5a), or you can click on the map the white square at the location of Lough Feeagh. When you point to any of the white squares on the map the name of the lake appears in a yellow message box. You also need to select the calibration lake from the *Calibration lake* drop-down list (Figure 5a). Calibration lake means that lake (or catchment of the lake – as is the case in the DOC topic) whose data have been used in quantifying the causal relationships in the Bayesian network for DOC. For the topic of *Water colour (DOC)* there are four calibration lakes available. Preferably you should choose as the calibration lake a lake that resembles the lake of interest. In this case it is easy, because Lough Feeagh is also one of the four available calibration lakes for this topic. When you select Lough Feeagh as the calibration lake, you see a blue edge to appear around the square showing the location of Lough Feeagh. The blue edge denotes that a lake is the selected calibration lake for the current topic.

Now you are ready to proceed to assessing the projected future DOC levels. At the bottom of the Bayesian network figure there are four nodes labelled as: *Predicted DOC (winter)*, *Predicted DOC (spring)*, *Predicted DOC (summer)*, and *Predicted DOC (autumn)*. Select one of these nodes (e.g. winter) by clicking on it, and you will see two distribution bars labelled as *Current* and *Predicted* on top of the Bayesian network figure. The bar representing the current state is divided into five classes having an equal probability. To set the current state click on any of the five classes. When you do that, the system shows the projected future distribution in the bar labelled as *Predicted*. If you want to change the selected current level, click again on the *Current* distribution, which changes all the five classes to have equal probabilities once again.

Here it was suggested that the current long term mean is between 5 and 10 mgC/l, so click the corresponding (green) class in the *Current* bar. In the *Predicted* bar you can observe that a significant increase in winter DOC levels is projected for Lough Feeagh. The winter DOC level is projected to be in 55% of years above 20 mgC/l, in 25% of years between 15 and 20 mgC/l, in 14% of years between 10 and 15 mgC/l, in 6% of years between 5 and 10 mgC/l, and in 1% of years below 5 mgC/l. A similar analysis for the remaining seasons reveals that DOC levels are projected to increase in all seasons.

b)
Select Poulaphuca as the lake of interest in the same manner as you selected Lough Feeagh in a). As Poulaphuca is not one of the calibration lakes, that one of the four available calibration lakes should be selected that is most similar in its behaviour to Poulaphuca. The similarity in behaviour depends on several factors, including soil type, land use and vegetation. Due to lack of data, the CLIME-DSS unfortunately does not help the user to assess if two sites are similar in terms of the above mentioned factors. Also, the analysis is assumed to more reliable for the region where the climate does not differ very much from that at the calibration site. The CLIME-DSS provides help in assessing how similar the climate is at the calibration site and at the site of interest. There is a climatic similarity indicator above the Bayesian network figure (Figure 5d). Moreover, you can check the *Show climatic similarity* check box above the map, which applies a mask that paints those regions white that are climatically far away from the calibration site. Doing this when Lough Feeagh is selected as the calibration lake shows that the climate at Poulaphuca is not too different from that of Lough Feeagh (the climatic similarity indicator shows a strong similarity, and Poulaphuca is not covered by the white mask – this is the case for the climate simulation results of any of the three available climate models). This is not surprising, as Lough Feeagh and Poulaphuca are geographically close to each other.

To study the projected future DOC levels in Poulaphuca proceed exactly in the same manner as you did with Lough Feeagh above in a).

c)
In the CLIME project there was no study site in southern Sweden. In order to assess a site not included into the set of CLIME sites, select from the *Lake of interest* drop-down list the first entry labelled as *New lake from map*. When *New lake from map* is active, you can pick any location on the map for analysis by clicking at it. After having selected *New lake from map,* click in southern Sweden to pick your lake of interest. You might want to select the *Peatlands and lakes* map from the *Map type* drop-down list to guide you in locating the study site in southern Sweden. The same map also shows that there are peat lands in southern Sweden suggesting that lakes may have problems with DOC.

Now you need to select that calibration lake whose behaviour most resembles the lake of interest in southern Sweden. As explained in b), the CLIME-DSS can assist you here just in terms of climatic similarity. To have a look at the climatic similarity between the calibration lake and the lake of interest, have the *Show climatic similarity* check box checked and keep an eye on the climatic similarity indicator above the Bayesian network figure. Say you have selected RCAO-E as the regional climate model from the *Model* drop-down list. When you now go through the four available calibration sites from the *Calibration lake* drop-down list, you can observe that none of the four available calibration lakes are climatically very far away from your lake of interest in southern Sweden. This is because no matter which calibration lake you select, your site of interest is not covered by the white mask. When looking at the climatic similarity indicator, Mustajoki seems to be climatically further away from southern Sweden than Lough Feeagh, Lough Leane, and Moor House. Caution is warranted here for a couple of reasons. Firstly, different regional climate models give

different results on climatic similarity. For example, the HadRM3p model suggests significantly smaller regions of similar climate. Secondly, and more importantly, other factors like land use and soil type can be very important drivers in determining how DOC levels of a lake respond to the climate change.

To study the projected future DOC levels in Poulaphuca proceed exactly in the same manner as you did with Lough Feeagh in a), and Poulaphuca in b). You might want to do the analysis using more than one calibration lake in order to assess how sensitive the results are on the lake whose data have been used in quantifying the causal relationships in the Bayesian network.

References

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Samuelsson, P. 2004. RCAO and HadRM3p simulation results with focus on CLIME lake sites. SMHI Rossby Centre, SE-602 36 Norrköping, Sweden. CLIME deliverable nr. 5. 70 pp.