The handle http://hdl.handle.net/1887/73639 holds various files of this Leiden University dissertation.

**Author:** Scherjon, F.

**Title:** Virtual Neanderthals: a study in agent-based modelling Late Pleistocene hominins in western Europe

**Issue Date:** 2019-05-28
REFERENCES

The software and data used in this research is credited according to the guidelines given at GitHub, the data storage and versioning service\(^{48}\).

**Paleoclimate data sets**


**Topographical data sets**


**Software tools used in this study**


**Literature**


---


References


272 Virtual Neanderthals


References


References


References


References


Linge, N. and A. Sutton, 2015. 30 Years of Mobile Phones in the UK: Amberley Publishing Limited.


Marks, J., 2012. My ancestors, myself. Fossil genomics is opening new windows to the past. But the view through them isn't as clear as we like to think. In *Aeon* 12.


RStudio: Integrated development environment for R 1.0.153, Boston, MA.


Speth, J.D., 2013. Thoughts about hunting: Some things we know and some things we don't know. *Quaternary International* 297: 176-185.


References


Wragg Sykes, R., 2010. Neanderthals in Britain: Late Mousterian Archaeology in Landscape Context, University of Sheffield, Department of Archaeology.


## APPENDIX 1: ABBREVIATIONS

### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABMS</td>
<td>Agent-Based Modelling and Simulation</td>
</tr>
<tr>
<td>ABM</td>
<td>Agent-Based Model(ling), can also be found under the terms Agent-Based Computational Modelling, Agent-Based Social Simulation, Multi-Agent systems, Distributed Artificial Intelligence, and Swarm Intelligence.</td>
</tr>
<tr>
<td>ABS</td>
<td>Agent-Based System.</td>
</tr>
<tr>
<td>AMH</td>
<td>Anatomically Modern Human(s).</td>
</tr>
<tr>
<td>BP</td>
<td>Before Present, where present is defined as 1950.</td>
</tr>
<tr>
<td>CLIMAP</td>
<td>Climate Map.</td>
</tr>
<tr>
<td>FR</td>
<td>Foraging range: The total area of land over which a hominin group moves and from which resource materials are taken in one year. This is equal to the annual range, the area that is covered for subsistence purposes in a complete year (MacDonell 1995).</td>
</tr>
<tr>
<td>GARP</td>
<td>Genetic Algorithm for Rule-Set Prediction.</td>
</tr>
<tr>
<td>HS</td>
<td>HomininSpace: The Hominini tribal level is today the scientific identification of humans and their ancestors as separated from the great apes, with which they form the family taxonomic unit of Hominidae (Wood and Richmond 2000). In popular language this is Anglicized to hominins. Space is the natural living dimension for individuals. Both the simulation research methods as well as archaeological excavations add their own temporal dimension to the usage of space. The generalized nature of the implementation of the system (without the specialized datasets that mark the case study for Neanderthals) suggests the name HomininSpace (no italics) for a simulation system that models hominin behaviour in the landscape and that is validated against archaeological data concerning hominin presence and absence. HomininSpace is the designation for the complete modelling and simulation system with associated documentation that has been developed in the context of the study described in this thesis.</td>
</tr>
<tr>
<td>IBM</td>
<td>Individual-Based Modelling.</td>
</tr>
<tr>
<td>ka</td>
<td>Kilo-Annum (thousand years) ago.</td>
</tr>
<tr>
<td>kya</td>
<td>Kilo (thousand) years ago.</td>
</tr>
<tr>
<td>LP</td>
<td>Late Pleistocene (versus Middle Palaeolithic). The Late Pleistocene is defined as the period from 126 ka up to 11.7 ka. It starts with the Eemian (MIS 5e) and ends with the Holocene (<a href="http://quaternary.stratigraphy.org/majordivisions/">http://quaternary.stratigraphy.org/majordivisions/</a>, <a href="http://www.stratigraphy.org/index.php/ics-chart-timescale">http://www.stratigraphy.org/index.php/ics-chart-timescale</a>, accessed 15 January 2018). Since the simulations in this study all end at 50 ka, the final part of the Late Pleistocene is not included in this research.</td>
</tr>
<tr>
<td>MAS</td>
<td>Multi-Agent Systems.</td>
</tr>
<tr>
<td>MAXENT</td>
<td>Maximum Entropy.</td>
</tr>
<tr>
<td>MH</td>
<td>Mid-Holocene point in time (~6 ka), reconstructed as very warm compared to current day temperatures.</td>
</tr>
<tr>
<td>My</td>
<td>Million Years.</td>
</tr>
<tr>
<td>Mya</td>
<td>Million Years Ago.</td>
</tr>
<tr>
<td>LGM</td>
<td>Last Glacial Maximum (~21 ka).</td>
</tr>
<tr>
<td>LMP</td>
<td>Late Middle Palaeolithic.</td>
</tr>
<tr>
<td>LUP</td>
<td>Late Upper Palaeolithic.</td>
</tr>
<tr>
<td>PMIP</td>
<td>Paleoclimate Modeling Intercomparison Project.</td>
</tr>
<tr>
<td>SAM</td>
<td>Spatial Analysis in Macroecology.</td>
</tr>
</tbody>
</table>
### Bioclimatic parameters

<table>
<thead>
<tr>
<th>Bioclimatic parameters</th>
<th>BIO1 = Annual Mean Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))</td>
</tr>
<tr>
<td></td>
<td>BIO3 = Isothermality (BIO2/BIO7) (* 100)</td>
</tr>
<tr>
<td></td>
<td>BIO4 = Temperature Seasonality (standard deviation *100)</td>
</tr>
<tr>
<td></td>
<td>BIO5 = Max Temperature of Warmest Month</td>
</tr>
<tr>
<td></td>
<td>BIO6 = Min Temperature of Coldest Month</td>
</tr>
<tr>
<td></td>
<td>BIO7 = Temperature Annual Range (BIO5-BIO6)</td>
</tr>
<tr>
<td></td>
<td>BIO8 = Mean Temperature of Wettest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO9 = Mean Temperature of Driest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO10 = Mean Temperature of Warmest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO11 = Mean Temperature of Coldest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO12 = Annual Precipitation</td>
</tr>
<tr>
<td></td>
<td>BIO13 = Precipitation of Wettest Month</td>
</tr>
<tr>
<td></td>
<td>BIO14 = Precipitation of Driest Month</td>
</tr>
<tr>
<td></td>
<td>BIO15 = Precipitation Seasonality (Coefficient of Variation)</td>
</tr>
<tr>
<td></td>
<td>BIO16 = Precipitation of Wettest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO17 = Precipitation of Driest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO18 = Precipitation of Warmest Quarter</td>
</tr>
<tr>
<td></td>
<td>BIO19 = Precipitation of Coldest Quarter</td>
</tr>
</tbody>
</table>

### Biome (Mega) classifications

<table>
<thead>
<tr>
<th>Original biome classification</th>
<th>Mega-biome classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical evergreen broadleaf forest</td>
<td>Tropical forest</td>
</tr>
<tr>
<td>Tropical semi-evergreen broadleaf forest</td>
<td></td>
</tr>
<tr>
<td>Tropical deciduous broadleaf forest and woodland</td>
<td></td>
</tr>
<tr>
<td>Warm-temperate evergreen broadleaf and mixed forest</td>
<td>Warm-temperate forest</td>
</tr>
<tr>
<td>Warm-temperate evergreen broadleaf forest</td>
<td></td>
</tr>
<tr>
<td>Warm-temperate rainforest</td>
<td></td>
</tr>
<tr>
<td>Wet sclerophyll forest</td>
<td></td>
</tr>
<tr>
<td>Cool evergreen needle leaf forest</td>
<td>Temperate forest</td>
</tr>
<tr>
<td>Cool mixed forest</td>
<td></td>
</tr>
<tr>
<td>Cool-temperate rainforest</td>
<td></td>
</tr>
<tr>
<td>Cool-temperate evergreen needle leaf and mixed forest</td>
<td></td>
</tr>
<tr>
<td>Temperate evergreen needle leaf forest</td>
<td></td>
</tr>
<tr>
<td>Temperate deciduous broadleaf forest</td>
<td></td>
</tr>
<tr>
<td>Cold deciduous forest</td>
<td>Boreal forest</td>
</tr>
<tr>
<td>Cold evergreen needle leaf forest</td>
<td></td>
</tr>
<tr>
<td>Temperate sclerophyll woodland and scrubland</td>
<td>Savanna and dry woodland</td>
</tr>
<tr>
<td>Temperate evergreen needle leaf open woodland</td>
<td></td>
</tr>
<tr>
<td>Tropical savanna</td>
<td></td>
</tr>
<tr>
<td>Temperate deciduous broadleaf savanna</td>
<td></td>
</tr>
<tr>
<td>Tropical xerophytic scrubland</td>
<td>Grassland and dry scrubland</td>
</tr>
<tr>
<td>Temperate xerophytic scrubland</td>
<td></td>
</tr>
<tr>
<td>Tropical grassland</td>
<td></td>
</tr>
<tr>
<td>Temperate grassland</td>
<td></td>
</tr>
<tr>
<td>Steppe</td>
<td></td>
</tr>
<tr>
<td>Xerophytic woods/scrub</td>
<td></td>
</tr>
<tr>
<td>Temperate grassland and xerophytic scrubland</td>
<td></td>
</tr>
<tr>
<td>Desert</td>
<td>Desert</td>
</tr>
<tr>
<td>Graminoid and forb tundra</td>
<td>Dry tundra</td>
</tr>
<tr>
<td>Cushion-forb tundra (cushion forb, lichen and moss tundra)</td>
<td>Tundra</td>
</tr>
<tr>
<td>Erect dwarf-shrub tundra</td>
<td></td>
</tr>
<tr>
<td>Low and high shrub tundra</td>
<td></td>
</tr>
<tr>
<td>Prostrate dwarf-shrub tundra</td>
<td></td>
</tr>
<tr>
<td>Tundra</td>
<td></td>
</tr>
<tr>
<td>Alpine grassland</td>
<td></td>
</tr>
</tbody>
</table>

Appendices
APPENDIX 2: SUPPLEMENTARY MATERIALS

HomininSpace consist of a computer application, associated input files, simulation results and documentation. This thesis describes the study in which the HomininSpace simulation system was developed and with this thesis come Supplementary Materials, both in the appendices and in separate files collected on a single DVD disk. The content of this DVD is listed in Table 56. Furthermore this appendix contains the posters that were presented at conferences and which are referred to in this work. Such materials are normally not easily accessible and therefore included here. All materials available on the DVD are also accessible online, via a service made available by the Data Archiving and Networked Services (DANS): https://doi.org/10.17026/dans-28h-bysx. Data has been submitted using the online archiving system EASY, upon which data is archived according to the guidelines of the international Data Seal of Approval, the ICSU-WDS, and the NESTOR seal for Trustworthy Digital Archives. Moreover, the metadata fields in EASY comply with the guidelines of the Dublin Core standard ensuring future availability.

Contents of the HomininSpace data disk

The Table 56 lists the items on the disk that accompanies this study. Bold face headers are the names of directories on the disk, starting at the root. The actual filenames as included on the disk are given in italics.

Table 56: Contents of the HomininSpace disk.

<table>
<thead>
<tr>
<th>\Documentation</th>
<th>\Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>HomininSpace ODD.docx / .pdf</td>
<td>Analysis results plots [scenario].pdf</td>
</tr>
<tr>
<td>HomininSpace – checkpoint database.docx</td>
<td></td>
</tr>
<tr>
<td>HomininSpace – thesis.docx / .pdf</td>
<td></td>
</tr>
<tr>
<td>Climate reconstruction - Fulco Scherjon - labreport.docx</td>
<td></td>
</tr>
<tr>
<td>HomininSpace_GE.kmz</td>
<td></td>
</tr>
<tr>
<td>HomininSpace - user manual 1.6.docx / .pdf</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AllData.csv</td>
<td>File with all simulations from all scenarios.</td>
</tr>
<tr>
<td>Batchresults_[scenario].txt</td>
<td>Results for all simulations from a scenario. One file for each scenario.</td>
</tr>
<tr>
<td>[Correlation output]</td>
<td>For each scenario files with correlation data for the Standard set, the Evolved set and the combined set with all simulations.</td>
</tr>
<tr>
<td>Top10 parametervalues.csv</td>
<td>Overview of the best 10 simulations for each scenario.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Data</td>
<td></td>
</tr>
<tr>
<td>Neandertal sites – north west Europe.xlsx</td>
<td>All checkpoints with associated intervals. Database with dating information for Neandertal sites for the simulation area. Also includes a list of MIS 6 sites (used for starting populations) and pure information points (that just register presence, but since no exact dating information is known, these are not used in validation of the results). Contains all checkpoints, monitoring checkpoints and starting locations of initial population groups.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>SAM Grid a_1_12.txt</td>
<td>Input grid cells.</td>
</tr>
<tr>
<td>Bintanja2008.txt</td>
<td>Reconstructed temperature and sea level values.</td>
</tr>
<tr>
<td>HomininSpace Climate Grid.txt</td>
<td>Climate data per grid cell.</td>
</tr>
<tr>
<td>HomininSpace Checkpoint List.txt</td>
<td>The actual input file with the checkpoint information. Derived from the Neandertal sites Excel file.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>SAM input files</td>
<td></td>
</tr>
<tr>
<td>Etopo1_bedrock.zip</td>
<td>Bedrock height values for selected area, XYZ format input file.</td>
</tr>
<tr>
<td>alt_2-5m_bil.zip</td>
<td>Worldclim.org input files, ecological data for current and past climates in high resolution (2.5 arc minutes).</td>
</tr>
<tr>
<td>bio_2-5m_bil.zip</td>
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<tr>
<td>wc_2_5m_CCSM_21k_bio.zip</td>
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</tr>
<tr>
<td>wc_2_5m_MIROC3.2_21k_bio.zip</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Source code</td>
<td></td>
</tr>
<tr>
<td>Workspace\HomininSpace</td>
<td>Source Code which provides the Java source code of the HomininSpace modelling framework. This is a Repast workspace and contains next to the source also administrative files.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Scripts for statistical analysis</td>
<td></td>
</tr>
<tr>
<td>Batch analysis HS results.R</td>
<td>R script for statistical analysis of the combined simulation result files.</td>
</tr>
<tr>
<td>Batch print HS results.R</td>
<td>R script to generate images that are used in the statistical analysis.</td>
</tr>
<tr>
<td>Analysis draw faces.R</td>
<td>R script to generate the Chernoff faces of the top 10 scoring individuals.</td>
</tr>
<tr>
<td>File Name</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Climate calculations.xlsx</td>
<td>Example calculations of secondary biomass.</td>
</tr>
<tr>
<td>HomininSpace Population Calculator.xlsx.</td>
<td>Interactive tool to see the effect on population structure of different parameters.</td>
</tr>
<tr>
<td>Output data</td>
<td>Files with batch simulation results</td>
</tr>
<tr>
<td>Summed data only.xlsx</td>
<td>Excel sheet containing the summed results for all output variables for all relevant simulations for all scenarios.</td>
</tr>
<tr>
<td>HS Logfile 2018-11-29 0045.txt</td>
<td>Example log file.</td>
</tr>
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<td>Movies with screen captures of running simulations</td>
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<td>1.888.579.450 8-10-2013 50.avi</td>
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<td>1.888.579.450 9-10-2013 50.avi</td>
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<td>1.888.579.450 22-10-2013 50.avi</td>
<td></td>
</tr>
<tr>
<td>1.888.579.450 23-10-2013 50.avi</td>
<td></td>
</tr>
<tr>
<td>Review by Iza Romanowska</td>
<td></td>
</tr>
<tr>
<td>HomininSpaceComments.docx</td>
<td>Word document with the source code review results.</td>
</tr>
<tr>
<td>Re HomininSpace et al (email 2016-12-11).txt</td>
<td>Verbatim email text with the overall impression and review results.</td>
</tr>
<tr>
<td>Earlier emails.txt</td>
<td>Email exchange about the review.</td>
</tr>
<tr>
<td>Applications</td>
<td>Tools used in the framework or during development</td>
</tr>
<tr>
<td>Quickview</td>
<td>Installation file for Quickview (needed to capture and view simulation movies).</td>
</tr>
<tr>
<td>Repast</td>
<td>Installation files for Repast 2.2.</td>
</tr>
<tr>
<td>SAM</td>
<td>Installation files for SAM 4.0 + documentation.</td>
</tr>
</tbody>
</table>
Appendices

Poster: Neandertals on the move. Or not. – ESHE 2015

NEANDERTALS ON THE MOVE. OR NOT.
A multi-parameter investigation of mobility types in the deep past

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HomininSpace
The aim of the Hominin space modelling and simulation system is to model, as realistically as possible, past hominin movement and persistence through time in a changing geological and geographical environment. Key characteristics are:
- Agent-based model (ABM).
- Fluctuating carrying capacity as key attractor.
- Parameterised and spatially explicit reconstructed paleo-environment.
- Year-by-year demographic model.
- Comprehensive database of archaeological checkpoints in space and time.

Hypothesis testing is done by comparing simulation results of hominin group presence in different scenarios against the archaeological record (simulation score). Results illustrate the effects of different parameters when reenacting hominin behavior in the past (Figure 1). Both "ebb and flow" and "sources and sinks" mobility types have been used to explain the Neandertal record of presence and absence (Bootsma et al. 2014) and have been implemented within the HomininSpace simulation system.

Model

Figure 1: HomininSpace: deconstructing the Neandertal model

Results

Conclusion: Sources and sinks mobility matches archaeology best
Comparing the archaeology with the results for the two mobility types suggest that the "sources and sinks" model matches the archaeological record best. Comparison for available resources is a major factor influencing mobility strategies. Possible explanations why the "sources and sinks" model scores higher and increase population levels consistently:
- When resources become scarce, hominins can sometimes survive, albeit at very low densities;
- During ebb and flow movement, groups will all converge on areas with high productivity;
- Sink populations will utilize the environment optimally, by being forced to use resources from areas that flow groups do not enter or leave when conditions become less favorable.

The implemented "sources and sinks" mobility model explains how repeated regional extinctions could have been an important factor in the demography of Neandertals. The enduring results also illustrate some of the advantages of ABM over other types of modelling.

Selected references

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Poster: How (not) to model Neandertal extinction. –ESHE 2016

How (not) to model Neandertal extinction

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If you handicap the competition, do not be surprised to win...

We analyzed existing simulation models for Neandertal demise. Each of the models
assumes a large difference between Neandertals and AMH (Fig. 1). Evidently, under such
conditions the replacement of Neandertals by AMH is inevitable (Fig. 2). Each model
was tested to implement an unmeasured (ambient) handicap for Neandertals:
- increasing mortality rates for Neandertals [6], and decreasing rates for AMH [1];
- decreasing growth rates for Neandertals, but increasing rates for AMH (due to
differences in technological development [3, 4, 5, 7] or in social organization [2]).

Reference

Handicap (assumptions)

Results

Model type

Zahrow 1989 [1]
Semantically small but effectively large demographic differences, with lower birthrate for N.
Large discrepancies in mortality and longevity, with an increment in N mortality of 1–2 % leading to extinction within 31 generations.
population model

Horse et al. 2015 [2]
Increasing social organisation for AMH.
Unavoidable replacement of N by AMH after 200–400 years.
mathematical

Horse 2011 [3]
Horse 1998 [7]
Murray 2004 [4]
Higher mortality rates for N.
Lower cultural level interacting with population size.
Higher death rates during childbirth and in death by hunting incidences between AMH and N.

N not replaced by AMH (model implemented by Murray 2003). Figure 2 uses the computed amplitude from [7] to estimate diffusion coefficients.
Replacement of larger N population by AMH.
Population grows amongst AMH despite adverse climatic conditions.
nonlinear mathematical

Figure 2 - The inevitable small replacement of N by AMH (figure adapted from [7]).

Conclusion: How to model Neandertals?

We introduce a conservative model which assumes no difference between N and AMH and uses only population size. This null model suggests that stochastic and allele effects (i.e., populations at low numbers are affected by decreasing growth rates) might have been sufficient for the Neandertals to have gone extinct (Fig. 3).

The research was supported by the Netherlands Organization for Scientific Research (N.W.O. VIDI Grant 016.154.013 (2015) and the N.W.O. Spinoza program (2013).
Comparing past climate models: CCSM versus MIROC

The LGM period is part of the focus of the Paleoclimate Modeling Intercomparison Project (PMIP, Joussaume and Taylor 1995) which is an international effort to evaluate models using widely varying climate conditions. Climate for this defining period in the past has been extensively documented using a diverse array of paleo-climate proxy data sets and is used to calibrate (new) climate models. The LGM climate differs significantly from today and can be interpreted as an extreme climate anomaly for which there is no present day analogue and which is difficult to reconstruct in simulations, but for which the major forcing factors are relatively well known. The LGM is a severe glacial period with changes in greenhouse gases, sea level and ice sheets. As such, climate parameters can be used to model extreme climate changes (Prentice et al. 2000). Due to the fact that conditions for the LGM are well studied, results from simulations including this period can be compared against other modelling results (Otto-Bliesner et al. 2006) and thus the dataset as a whole gains in confidence.

WorldClim provides two sets of data for the Last Glacial Maximum (LGM, around 21ka): the Community Climate System Model (CCSM) and the Model for Interdisciplinary Research On Climate (MIROC). Both are coupled general circulation models, with MIROC developed at the Center for Climate System Research (CCSR) at the University of Tokyo (Hasumi and Emori 2004) and CCSM designed at the University Corporation for Atmospheric Research (UCAR) (Collins et al. 2006). MIROC couples models for atmosphere, land, river, sea ice and ocean where CCSM couples models for land, sea-ice, ocean and atmosphere. MIROC is available upon request for collaborative researchers (http://ccsr.aori.u-tokyo.ac.jp/~yangpeng/source_center.htm, accessed 25 July 2013), where CCSM is actively developed into a successor named Community Earth System Model (CESM, http://www2.cesm.ucar.edu/, accessed 25 July 2013). Both are used primarily for future climate predictions, for instance by the Intergovernmental Panel on Climate Change (IPCC) (Hamilton 2007).

The reconstructed LGM environments from CCSM and MIROC are different. See Figure 94 for a visual comparison of the most relevant datasets. Especially temperatures as simulated by CCSM are generally lower than those from MIROC, but precipitation levels are also lower. These differences are likely to influence simulation results (Olfert et al. 2011). Both models are however among the best for modelling LGM circumstances (Maris et al. 2012; Otto-Bliesner et al. 2007). Instead of averaging the results of the two models as done by Waltari et al. (2007), the underlying research uses one single model. CCSM has
been selected due to the fact that the available data from MIROC were created using version 3.2 which contains an error in the land surface scheme. Correcting this error, as has been done in 3.2.2, would lower the temperature values (Maris et al. 2012, 804).

The chosen colour scheme for the temperature maps (values in Table 3) is constructed based on the colours used by The Weather Network (example in http://scsjournal.files.wordpress.com/2011/11/the-weather-network.jpg, accessed 21 July 2013). The colour scheme for the precipitation values is inspired by the Canadian weather reports (http://scsjournal.wordpress.com/, accessed 21 July 2013). Note that the temperature values in the WorldClim database must be divided by 10 to get degrees Celsius.
Appendices

Virtual Neanderthals

BIO1 = Annual mean temperature

BIO5 = Max temperature of the warmest month

BIO6 = Min temperature of the coldest month

BIO12 = Annual precipitation

Figure 94: Overview of the results for the main biological values for CCSM (left) and MIROC climate models with unified colour coding schemes.