# Impacts of Heinrich events upon Human existence potential in Europe

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# Abstract

Heinrich events are extremely cold climate events during the last glacial period. The role of climate on Human Existence Potential (HEP) during such extremes, is not sufficiently studied. By reproducing climate variables for the extremely cold and warm cycles using an Earth System Model, an HEP model, and archaeological data, we estimate the HEP over Europe for the stadial and interstadial times which correspond to the two Upper Palaeolithic technocomplexes, namely, the Late Gravettian and Aurignacian. By introducing some other diagnostic quantities such as Environmental Human Catchment, which defines an area of high HEP, cooling-aridity index, and Least Cost Path among colonized people, we examine some aspects of population dynamics in these epochs.

# Abstract

It is found that consecutive extremely cold and warm cycles, correspond to the contraction and expansion of areas of high HEP. This, supports the hypothesis of repetitive depopulationrepopulation cycles ancient humans. Regarding to the much debated issue of the survival location of Neanderthals, we show that the western coastlines of European terrain had such a suitable and stable HEP for all human taxa, including the Neanderthals, to survive the Heinrich events.

# Introduction

- Heinrich events (HEs)[1] are marked by layers of ice-rafted debris (IRD), indicating a remarkable source of fresh cold water from melting icebergs, discovered in marine sediment cores from a wide swath of the subpolar North Atlantic[2].
- HEs occurred repeatedly during the coldest phases of millennial-scale climate oscillations called Dansgaard-Oeschger (D-O) cycles and are assumed to have originated from the episodic discharge of massive numbers of icebergs from the Hudson Strait region into the North Atlantic Ocean[1,3]. Each HE cycle occurred every 3,000-8,000 years.

# Introduction

- Hunter-gatherers encountered hostile climate change during last glacial period in Europe[4,5] and a massive diminution has been reported by some diachronic studies[6,7] during the Late Gravettian technocomplex as one of the earliest technological phases that expanded all over Europe.
- Some deep-sea and loess records indicate that the final demise of the Neanderthal populations coincided with the onset of abruptly forced climate change during HE 4[8,9].
- Climate forces are one of the main drivers of human population dynamics and distribution of archaeological sites is probably confined by environmental conditions.

# Introduction

- The impacts of extreme climate events on the Human Existence Potential, such as the warm interstadials and the intervening cold stadials during the Upper Paleolithic Aurignacian ($\approx$ 43-33 kya) and Late Gravettian ($\approx$ 30-25 kya) periods are not yet well understood.
- The aim of this study is to address these deficiencies by simulating both extreme cold stadials and warm interstadial events and our improved HEP model.
- HEP in this study indicates the probability of human existence potential which is estimated by terrestrial climate conditions, carrying capacities of available resources, and accessibility of the locations based on topography, glaciers, water bodies, and forests[10].

# Materials and Methods

- **Archaeological data**: Archaeological data, taken from CRC 806 "Our Way to Europe" database (`https://crc806db.uni-koeln.de/`), represent georeferenced sites of hunter-gatherers across Europe for two chronological periods: Aurignacian, and Late Gravettian technocomplexes in Europe.
- **Paleoclimatic data**: The NCAR Community Climate System Model version 4 (CCSM4) with components for the atmosphere, ocean, land, and sea ice is used in this study for simulating Earth's climate during the Heinrich events. We impose a surface freshwater flux anomaly of $0.25Sv$ over 100 years, which is uniformly distributed over the northern North Atlantic ($50^\circ - 75^\circ N, 63^\circ W - 4^\circ E$).

# Materials and Methods

- **Human Existence Potential (*HEP*) Model**: HEP in this study represents the environmental suitability for a given geographical location for humans to live in. It utilizes logistic regression with second-degree polynomial based on a presence and absence record for suitable climatic predictors[10].
- **Environmental Human Catchment (EHC)**: Environmental Human Catchment (EHC) is extracted from *HEP* pattern by defining local maximum surrounded by local low *HEP*, determining the associated upflow of each grid point to the maximum point. Close catchments are merged into a bigger one.

# Results and Discussion

- A basic estimation of spatial distribution of the human existence potential (HEP) during the Late Gravettian and Aurignacian techno-complexes.
- There is a significant disparity between HEP during extreme cold stadials and warm interstadials of the upper Upper Palaeolithic (Fig. 1). While the climate was not favorable to stable colonization during cold stadials far from the western coasts, it was suitable in warm interstadials.

# HEP during the Aurignacian and Late Gravettian

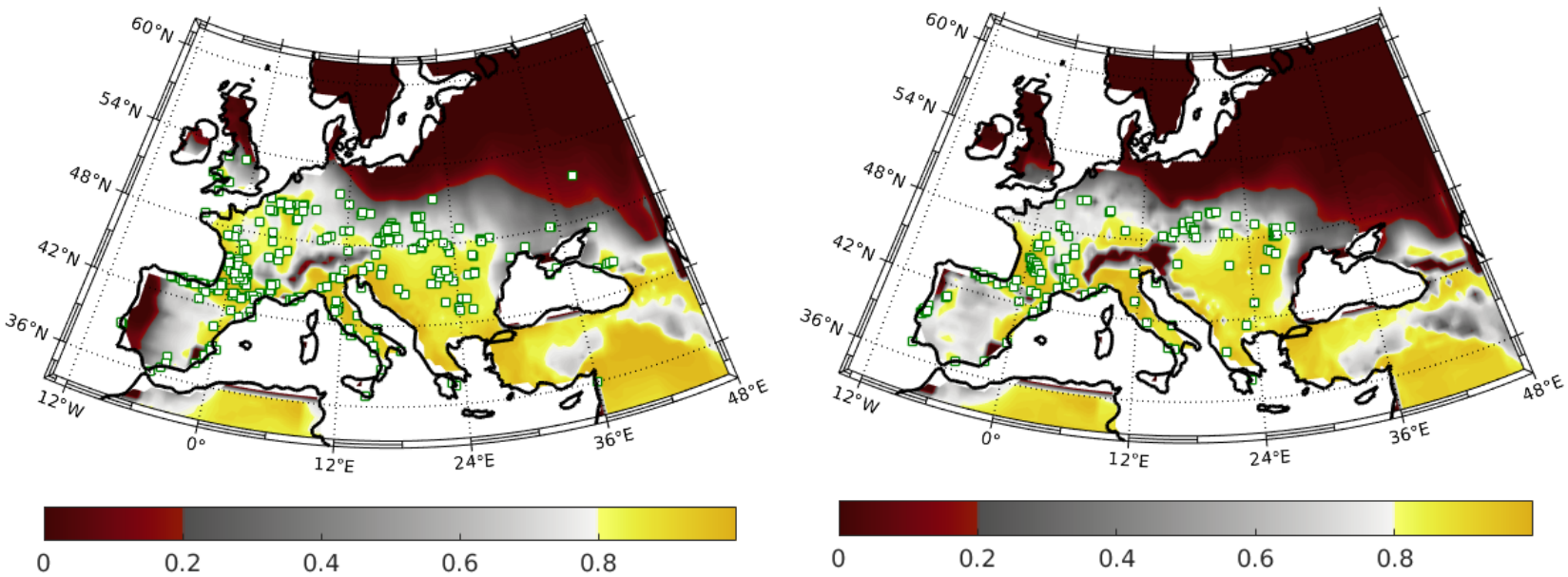


Figure: Human Existence Potential (HEP) of the warm interstadials during the Aurignacian (left panel) and Late Gravettian (right panel) technocomplexes. Excavation sites are presented as squares.

# HEP during the Aurignacian and Late Gravettian

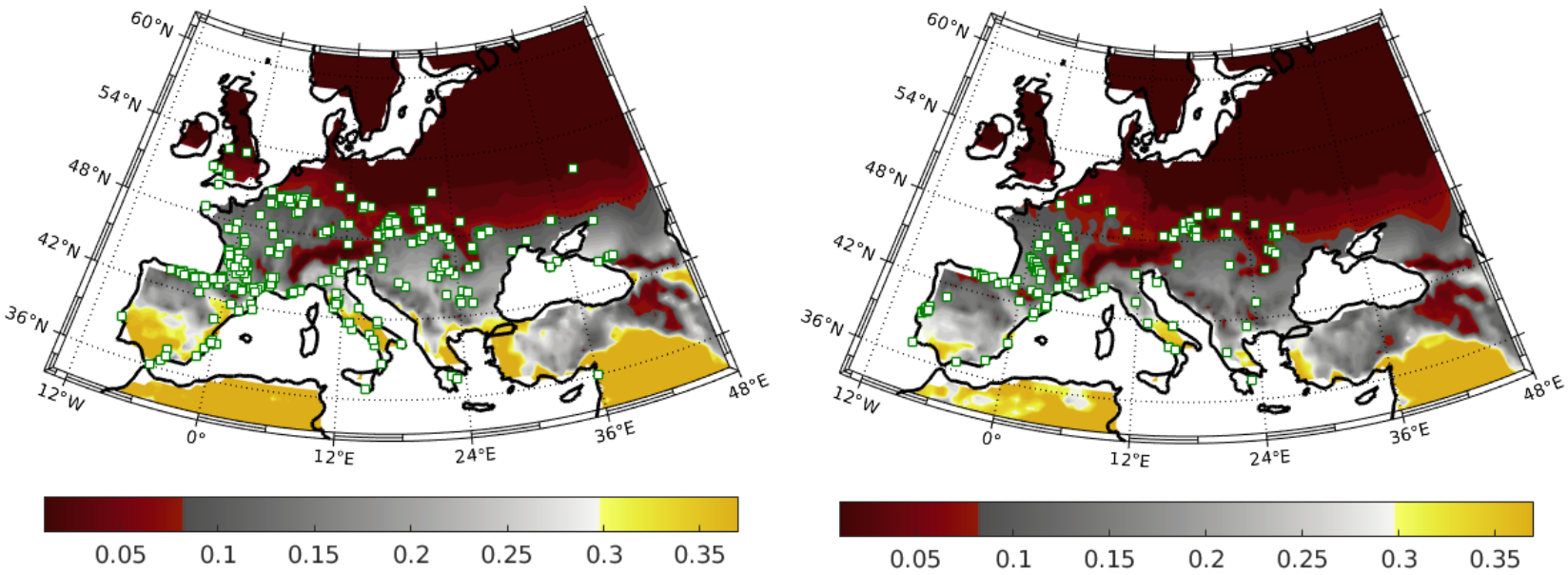


Figure: Human Existence Potential (HEP) of the cold stadials during the Aurignacian (left panel) and Late Gravettian (right panel) technocomplexes. Excavation sites are presented as squares.

# Cooling-Aridity Index (CAI)

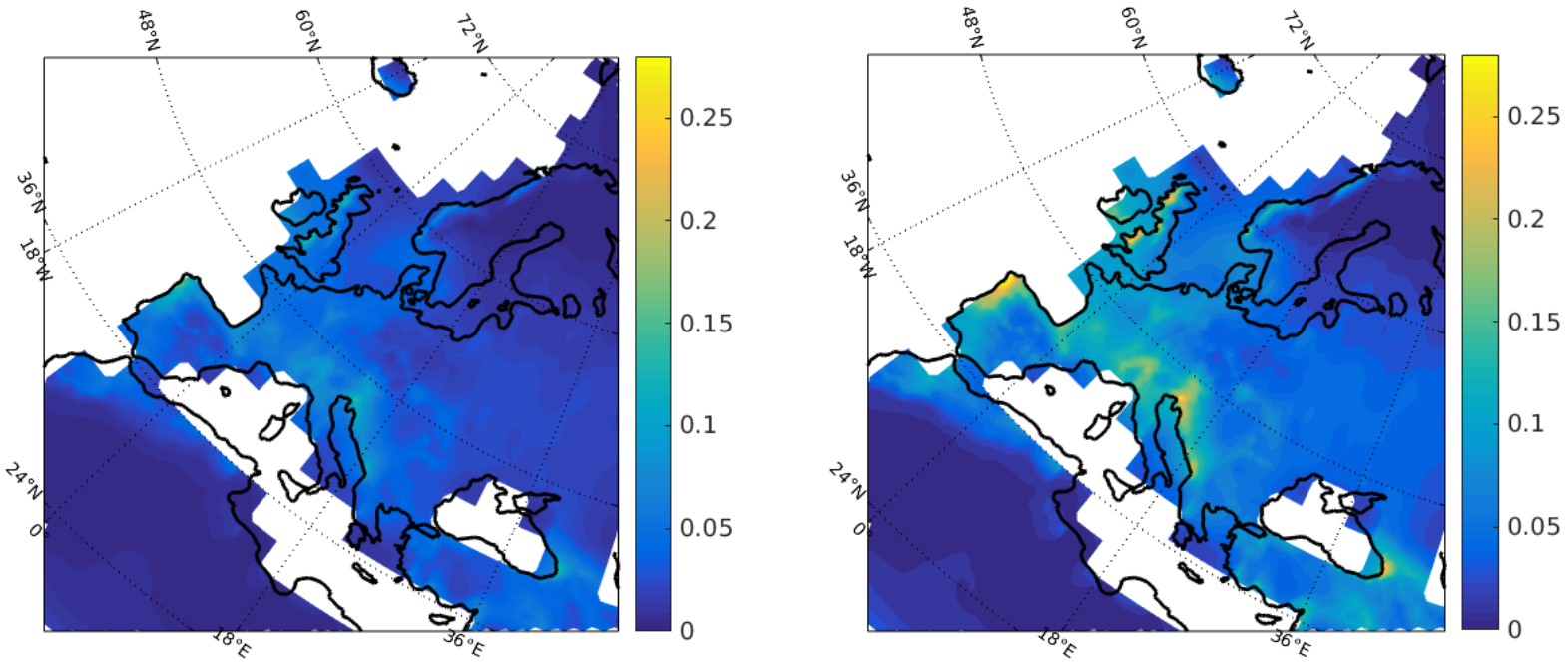


Figure: Spatial distribution of Cooling-Aridity Index (CAI), extracted by multiplication of temperature by precipitation normalized by maximum of each variable according to feature scaling, for extreme cold (left panel) and warm (right panel).

# Environmental Human Catchments (EHC)

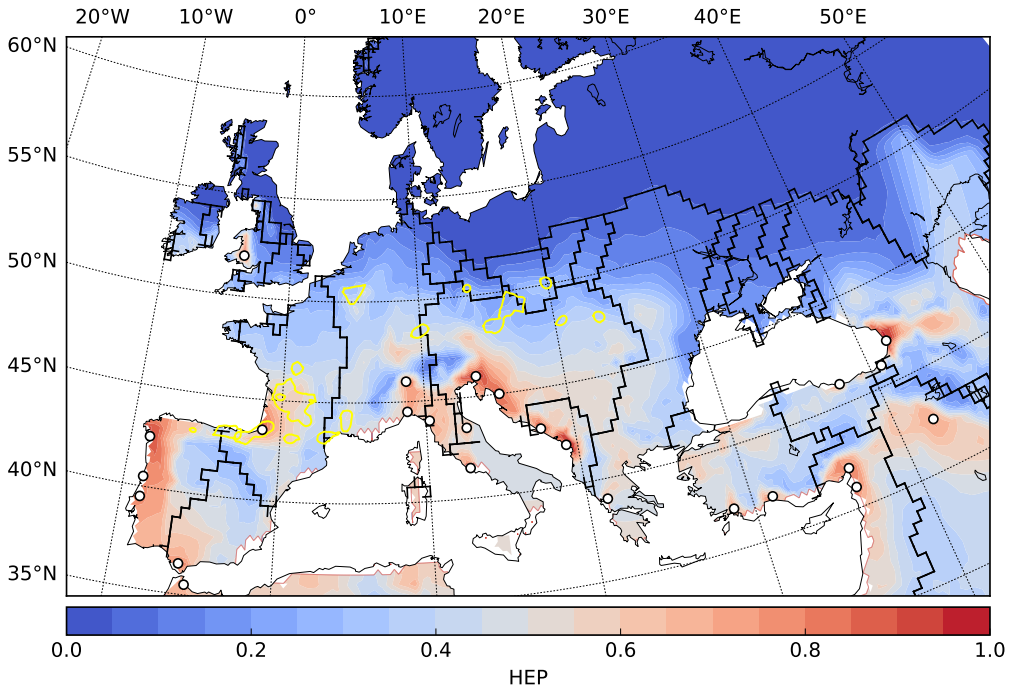


Figure: Environmental Human Catchments (EHC) during extreme cold period, illustrated as black solid lines, during Aurignacian technocomplex. White circles present excavation sites on the left panel and maximum HEP of each catchment on the right panel.

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