

Appendix:
Occupation and settlement through time:
Applying the human existence potential model
to European societies

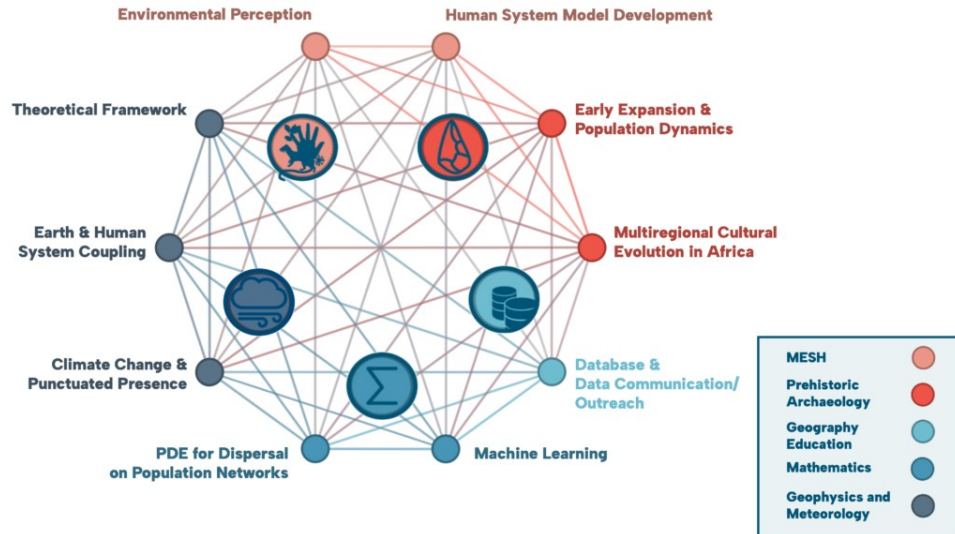
Dr. Christian Wegener

Prof. Dr. Yaping Shao

Institute for Geophysics and Meteorology – University of Cologne

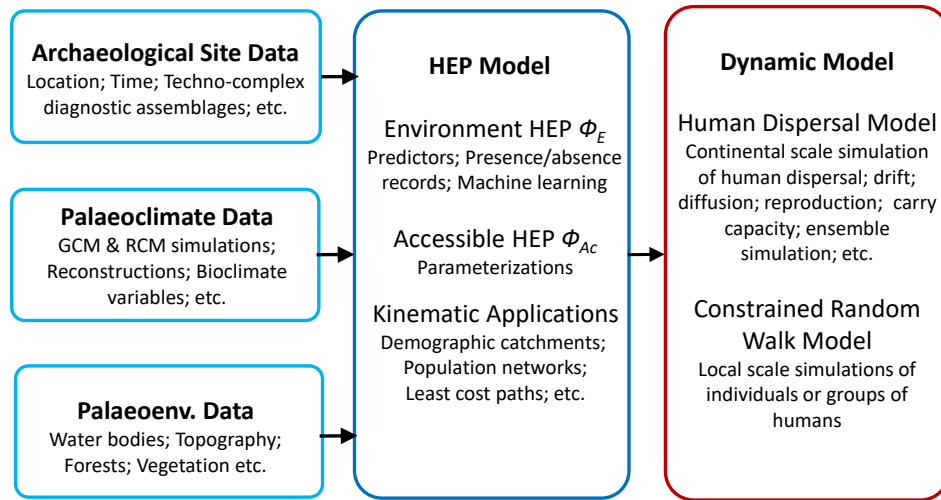
EGU2026

HESCOR Project



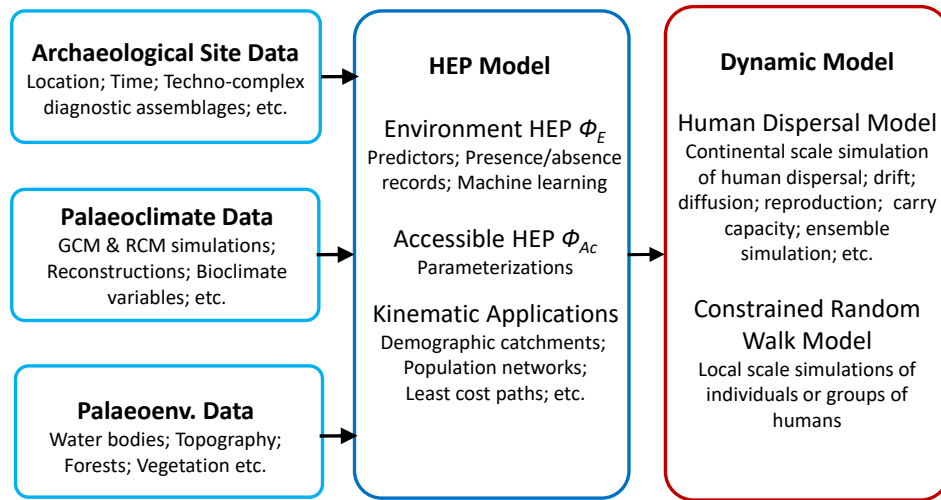
- **Interdisciplinary Project with ten Work Packages addressing the coupled human-Earth system**
- **Collaboration and communication across disciplines are essential for the project**
- **Coordinated System of empirical data, theoretical insights, and computation tools**

“Our Way” Framework



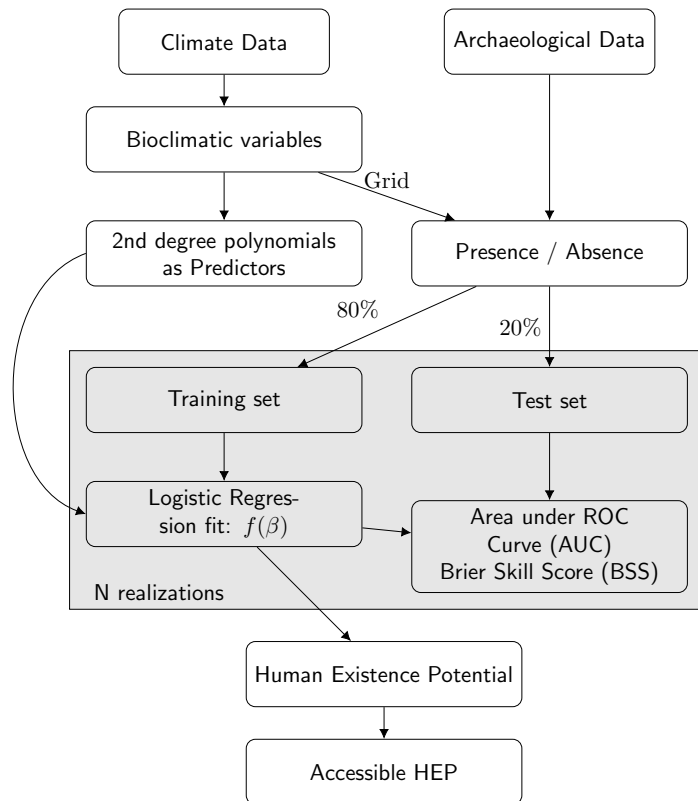
- **Modelling Framework first established in final CRC 806 phase (2019-2022)**
- **Combines Archaeological site locations and age with paleoclimate reconstructions and environmental data**
- **Human Existence Potential Model (HEP) combines the data through logistic regression**
- **Further constraints are introduced through the Accessible HEP based on parameterizations**

“Our Way” Framework



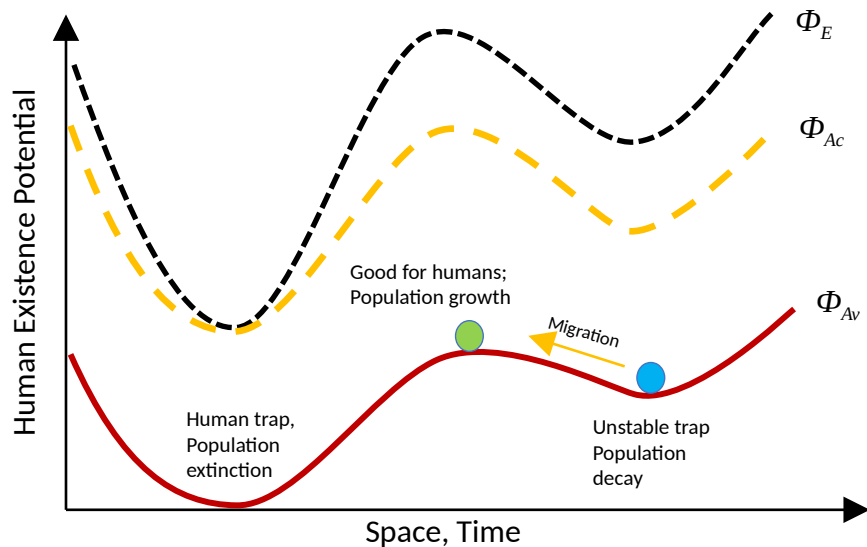
- **HEP Results give an estimation of possible occupation for a specific time (slice)**
- **Can be used for further analysis, or as input for dynamic models**
- **HDM focuses on large scales (societies, density based, Eulerian view)**
- **CRWM / CABM focuses on local scales (individuals, agent based, Lagrangian view)**

HEP Details [1,2]



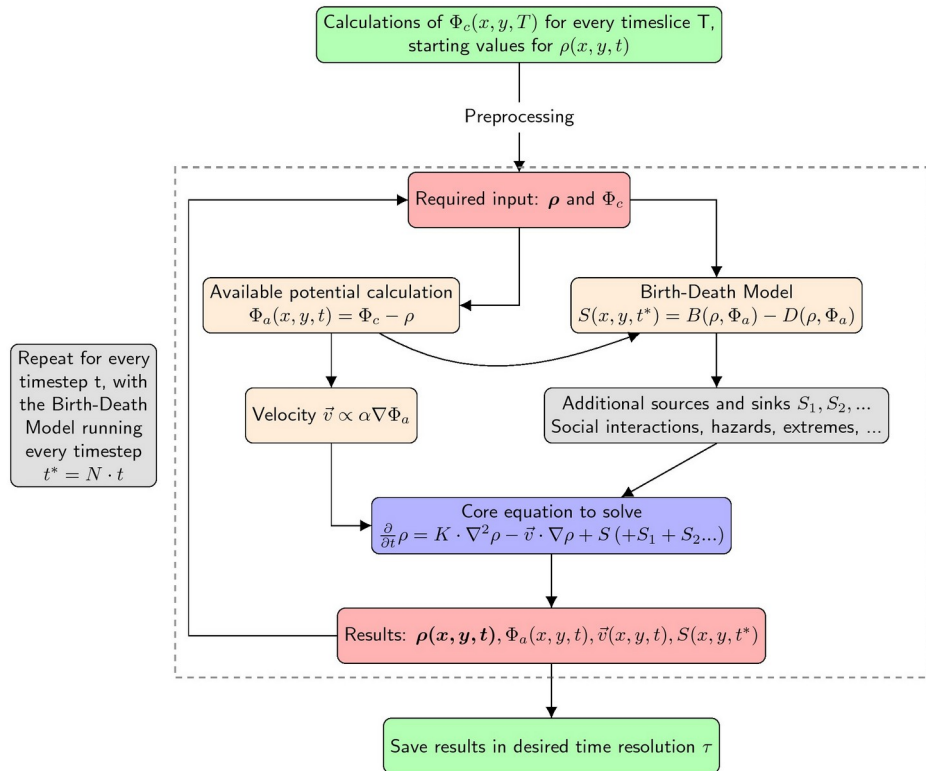
- Based on the grid given by the climate variables, a presence / absence record is created with the site data
- Climate variables & further inputs are used as predictors using 2nd degree polynomials and linear combinations of each variable
- Random or structured 80/20 Training and Test split of the data for each realization before fitting with a logistic regression
- Scores for evaluation, average and standard deviation over all N realizations
- Further optional constraints by AccHEP

HEP Details [2,4]



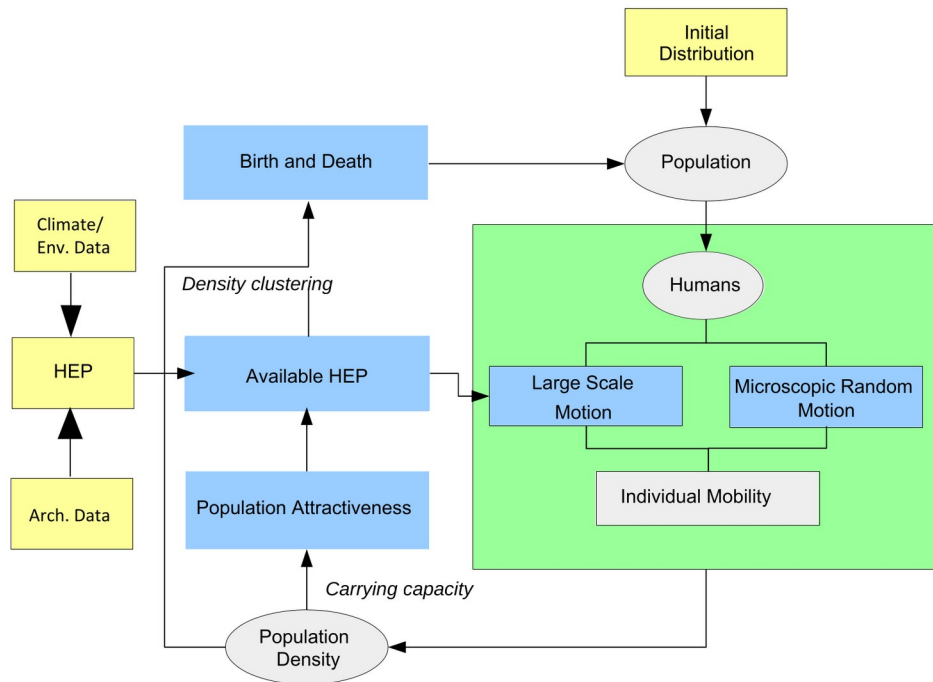
- The HEP Score can be interpreted as a potential surface if multiplied with the environmental carrying capacity (CC)
- The AccHEP further constrains how much of the CC is usable
- The Available HEP includes the existing number of humans (in the dynamic models), diminishing the amount of available resources

HDM Details [4]



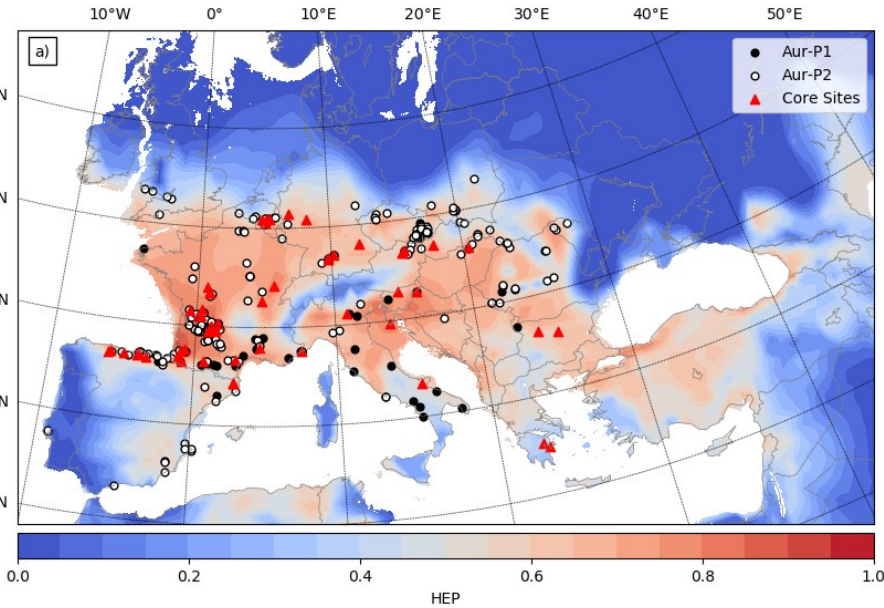
- **Human Dispersal Model (HDM) utilizes the HEP fields to calculate migration and simple population dynamics**
- **Requires additional parameters (reproduction rate, max. velocity, ...)**
- **Results include density distribution of human occupation**

CABM / CRWM Details [3,5]

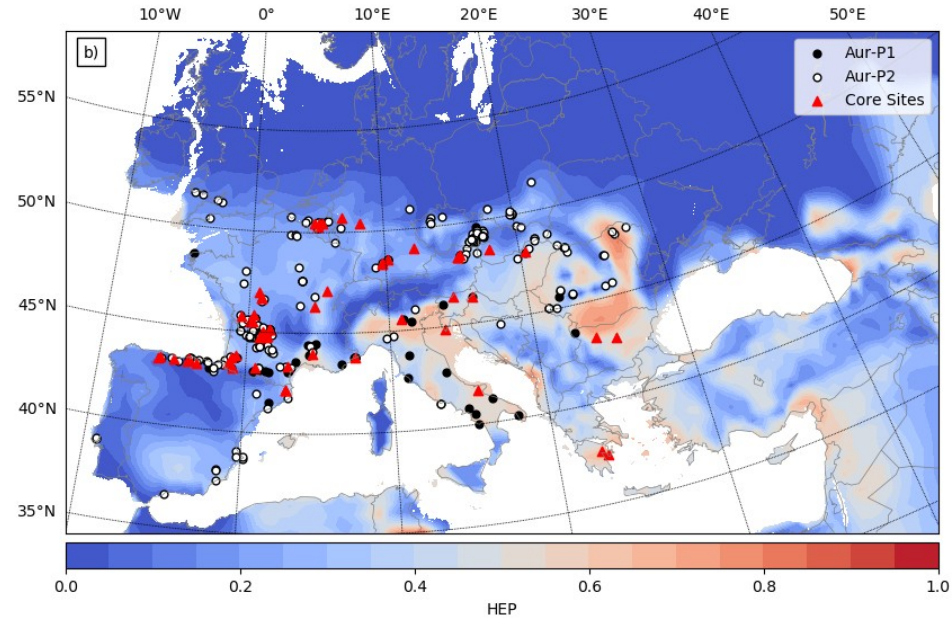


- **Constrained Agent Based (Random Walk) Model CABM / CRWM**
- **Based on the same equations as the HDM, but uses individual agents instead of densities**
- **Suitable for shorter time frames and domain sizes**

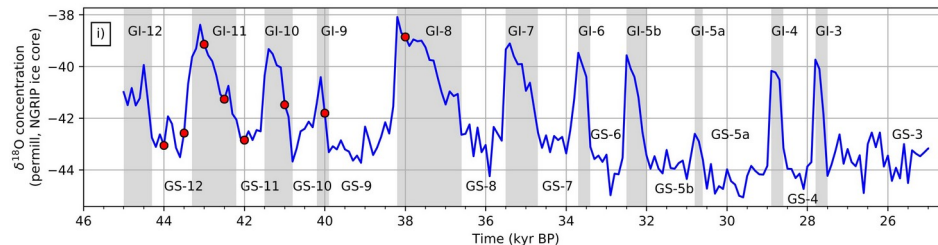
Example: HEP for climate extremes (Aurignacian) [2]



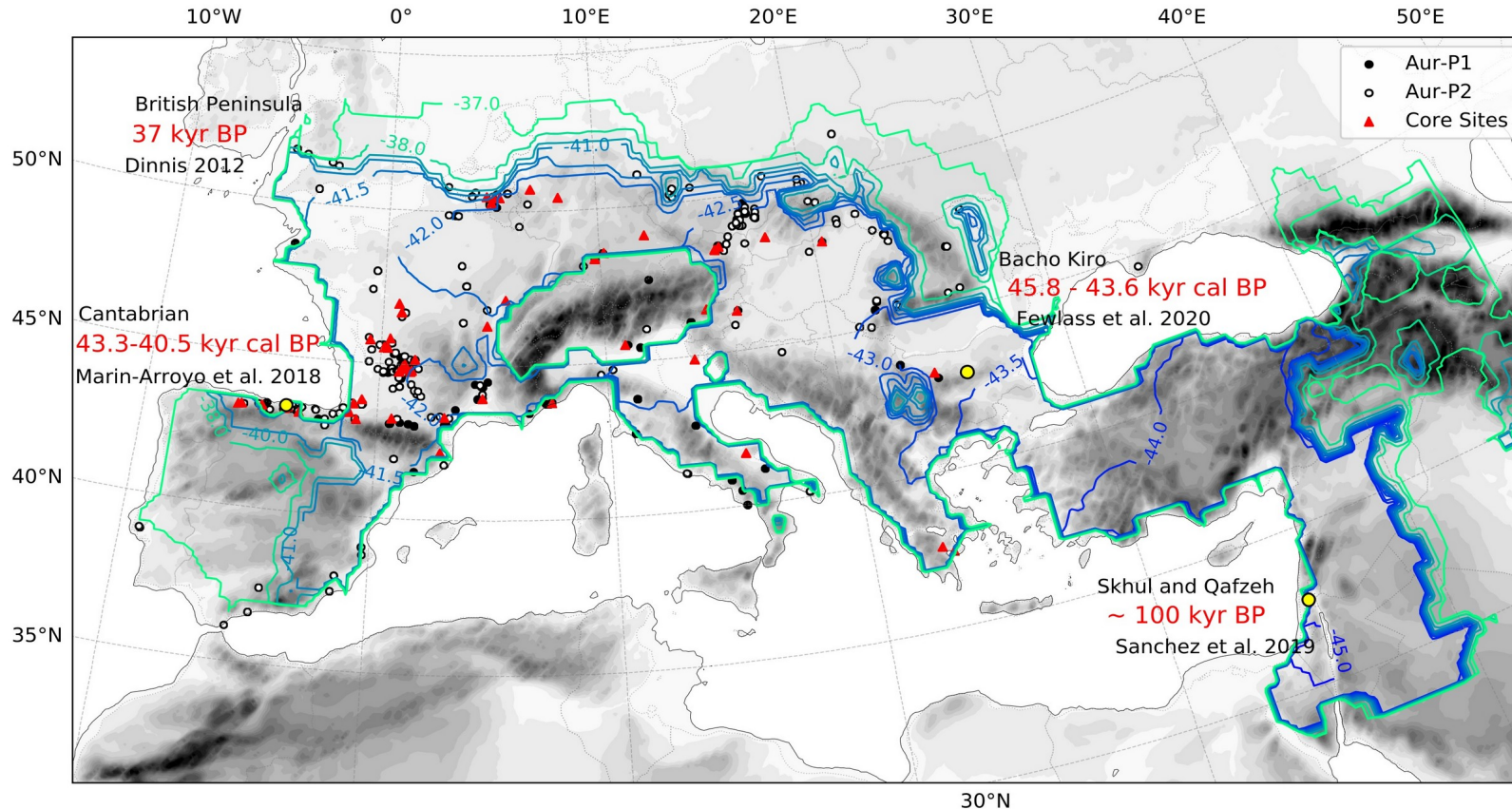
HEP for warm phases (GI-#)



HEP for cold phases (GI-#)



Example: First Arrival Times calculated by HDM [4]

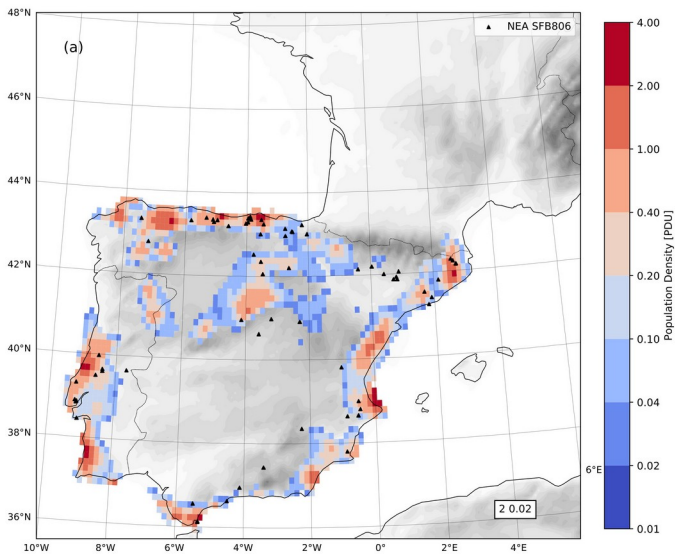


Start of the HDM simulation in the Levante at 45 ka bP

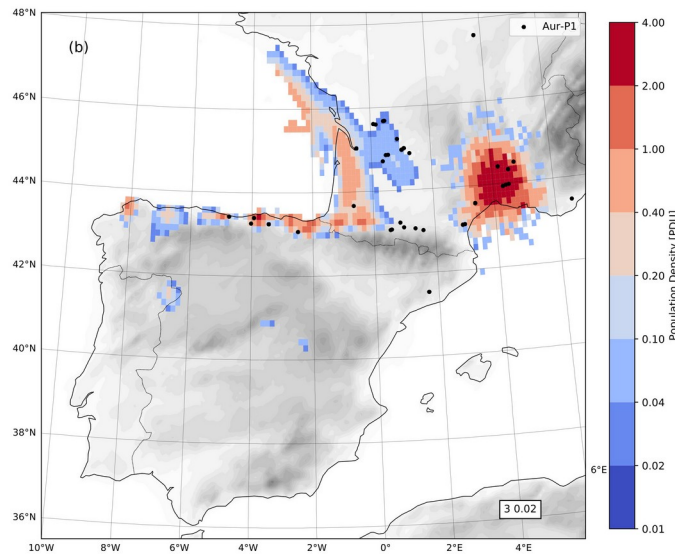
Reference Points (yellow) and age estimations for comparison

Example: Possible Population ad-mixture Neanderthals & AMH [5]

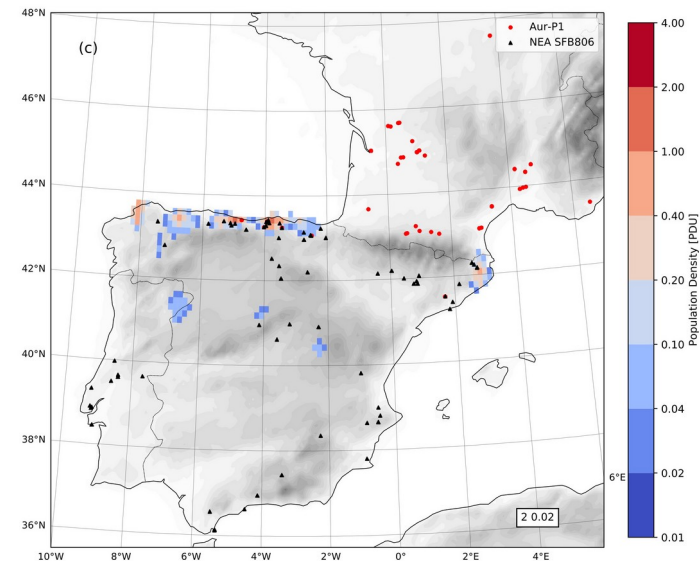
Neanderthal Occupation



Modern Human Occupation



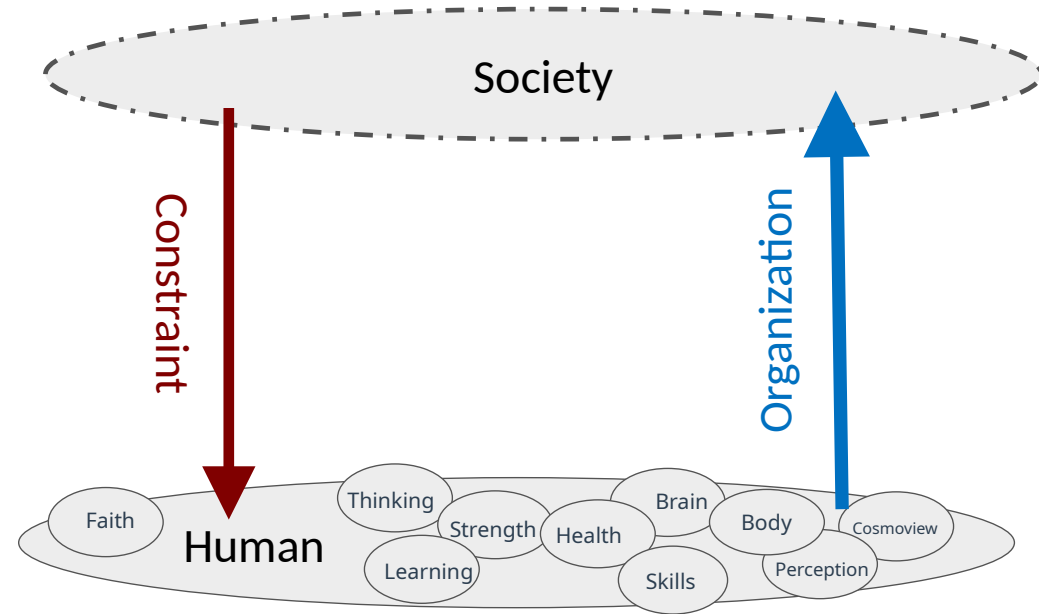
Mixed Population



Ensemble and time averages over 42-38 ka bP of population density calculated by agent distribution

Outlook

- Inclusion of Agency of individuals, groups of individuals and societies in the models
- Quantification of complex concepts to incorporate into numeric models is difficult
- Individuals form societies, which constrain the individuals in several aspects
- Multi-Layer approach to represent the constrain - organization connection



References

- [1] Klein et al. (2021), Human existence potential in Europe during the Last Glacial Maximum, *Quat. Int.*, Vol. 581-582, 7-27, <https://doi.org/10.1016/j.quaint.2020.07.046>
- [2] Shao et al. (2021), Human-existence probability of the Aurignacian techno-complex under extreme climate conditions, *Quat. Sci. Rev.*, Vol. 263, 106995, <https://doi.org/10.1016/j.quascirev.2021.106995>
- [3] Klein et al. (2023), Assessing climatic impact on transition from Neanderthal to anatomically modern human population on Iberian Peninsula: a macroscopic perspective, *Sci. Bul.*, Vol. 68, 1176-1186, <https://doi.org/10.1016/j.scib.2023.04.025>
- [4] Shao et al. (2024), Reconstruction of human dispersal during Aurignacian on pan-European scale, *Nat. Com.*, Vol. 15, 7406, <https://doi.org/10.1038/s41467-024-51349-y>
- [5] Shao et al. (2025), Pathways at the Iberian crossroads: Dynamic modeling of the middle-upper paleolithic transition, *PLoSone*, Vol. 20(12), e0339184, <https://doi.org/10.1371/journal.pone.0339184>

Code base: Github

- **Currently being build to store all HESCOR relevant code on a central platform**
- **Will include the “Our Way” framework in the future, HEP code is already available**

<https://github.com/HESCOR>





Human & Earth System
Coupled Research

<https://www.hescor-project.com/>

