# CliMar – Climate Model Simulations for Maritime Dependencies in Antiquity

## Extended Abstract

### Project Context and Objectives

CliMar constitutes the climate modelling component of the ERC Consolidator project *MarDepend – Maritime Dependencies in Antiquity* (https://cordis.europa.eu/project/id/101170294, PI: Pascal Warnking, Trier University). MarDepend investigates the structural dependence of ancient societies on maritime trade networks, with a particular focus on the city-state of Syracuse (Sicily) around ~400 BCE. The project adopts a highly interdisciplinary framework, integrating historical analysis, archaeology, oceanography, marine engineering, and economic modelling to reconstruct and quantify how environmental conditions shaped trade connectivity, economic resilience, and geopolitical dynamics in antiquity.

Within this framework, CliMar provides the physically consistent climate boundary conditions required to simulate ancient seafaring environments. Specifically, it aims to reconstruct the atmosphere–ocean state of the Mediterranean and adjacent regions at temporal and spatial resolutions sufficient to resolve wind systems, wave fields, and ocean currents relevant for navigation and ship performance.

### Methodological Approach

CliMar will generate a comprehensive set of paleoclimate simulations centered on ~400 BCE, a period of major socio-economic transformations in the Mediterranean. The modelling strategy is structured in two complementary phases:

1. **Global-to-Regional Downscaling Framework**
    - Transient Holocene simulations performed with the MPI Earth System Model (MPI-ESM) will provide large-scale boundary conditions.
    - From these simulations, high-frequency (sub-daily) output fields will be extracted to capture variability in winds, surface fluxes, and ocean circulation.
    - These outputs will drive high-resolution regional climate model (RegCM) simulations over the Mediterranean basin, resolving mesoscale atmospheric dynamics and regional ocean processes critical for maritime conditions.
    - The resulting datasets will provide dynamically consistent reconstructions of winds, waves, and currents, enabling downstream applications such as ship routing simulations and performance modelling.
2. **High-Resolution Global Time-Slice Simulations**
    - In a second phase, the ICON model will be configured in a paleoclimate setup to simulate a dedicated time slice around ~400 BCE at high spatial resolution.
    - These simulations will provide an alternative representation of the climate system without relying on regional nesting.

- A systematic comparison between ICON simulations and the downscaled MPI-ESM framework will be conducted to assess uncertainties and evaluate the added value of regional versus global high-resolution approaches.

**Scientific and Interdisciplinary Impact**
The CliMar simulations will constitute a unique, high-resolution reconstruction of Mediterranean climate conditions during antiquity. These outputs will directly feed into other components of MarDepend, including:

- Computational Fluid Dynamics (CFD) simulations of ancient ship performance under realistic environmental forcing,
- Numerical reconstruction of maritime trade routes and travel times,
- Integration with archaeological datasets (e.g., amphora distributions, coin circulation, inscriptions),
- Development of formal economic models quantifying trade efficiency and vulnerability.

By linking climate dynamics with human systems, CliMar will enable a quantitative assessment of how environmental variability influenced connectivity, risk, and resilience in ancient maritime economies.

**Computational Requirements and Justification**
The project requires substantial high-performance computing resources due to:

- High-frequency output computing time and storage from MPI-ESM time slice,
- Computationally demanding ICON paleoclimate time-slice experiments,
- Large data volumes necessary to resolve sub-daily variability relevant for marine applications.

These requirements make DKRZ an essential infrastructure for the successful execution of CliMar.

**Outlook**
CliMar will deliver a novel climate data foundation for the study of ancient maritime systems, bridging paleoclimate modelling and historical-economic analysis. The project advances both Earth system science—through the evaluation of modelling strategies in paleoclimate contexts—and the digital humanities, by enabling physically grounded reconstructions of past human–environment interactions.