EGU25-18588, updated on 12 May 2025
https://doi.org/10.5194/egusphere-egu25-18588
EGU General Assembly 2025

The Ecotron Time Machine – Simulating Climate Change in Controlled Environment Facilities

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Controlled Environment Facilities (CEFs) – including phytotron, ecotron, and lysimeter systems – are essential tools in experimental plant research. Studies conducted in CEFs have substantially advanced our understanding of ecological, physiological, and molecular responses to environmental factors, and have played an important role in the development and parameterization of mechanistic models.

Until recently, climate change research in controlled environments primarily focused on the static manipulation of a single (or few) parameters, notably temperature. However, modern CEFs now enable the highly precise, simultaneous control of multiple environmental variables, such as temperature, VPD, light, soil temperature, and soil moisture, as well as the accurate manipulation of atmospheric gases (e.g., CO and ozone).

The ability to maintain these factors at high temporal resolution effectively turns CEFs into “time machines,” allowing researchers to investigate plant and model-ecosystem responses under realistic climate change scenarios. Although the technical implementation of complex climate series has become more feasible, the core challenge lies in generating climate series that capture potential future conditions while avoiding oversimplification and meeting the scientific requirements for standardization and reproducibility.

In this contribution, we present examples from various experiments conducted at the TUM Model EcoSystem Analyser (TUMmesa). These range from incremental manipulation of individual environmental variables, through the replication of historically recorded climate series, to the dynamic downscaling of global climate models driven by representative concentration pathway (RCP) scenarios.

These recent advancements highlight the potential of modern CEFs to deepen our understanding of plant-environment interactions and support robust investigations of climate change impacts on terrestrial ecosystems.