The investigation of the global structural properties of the climate system (CS) plays a central role for the provision of a unifying picture of climate variability and climate change on a large variety of scales and is of outstanding importance for the quest for reliable metrics to be used in the validation of climate models (CMs). The CS can be seen as a complex, non-equilibrium system, transforming potential into mechanical energy as a thermal engine, generating entropy by irreversible processes, and keeping an approximate steady state by balancing the thermodynamic fluxes with the surrounding environment. We move from the thermodynamical perspective pioneered by Lorenz by means of theoretical studies, numerical simulations performed with hierarchies of CMs, ranging from minimal models to state-of-the-art coupled atmosphere-ocean models, and, where possible, observations. We take advantage of both the tools of the phenomenological theory of non-equilibrium thermodynamics and, from a more fundamental point of view, of the recent developments of non-equilibrium statistical mechanics, along the lines of the response theory developed by Ruelle. The main goals of this interdisciplinary project can be summarized as follows:

- Advances in the thermodynamic description of the CS and planetary bodies, re-analysis of the hydrological cycle and of the atmosphere-ocean interaction;
- Thermodynamic re-examination of mechanisms involved in past, present and future climate variability and change with CMs of various degrees of complexity;
- Definition and implementation of a new generation of diagnostic tools for auditing CMs and for analysing observable (satellite) data;
- Application of the response theory and Kramers-Kronig relations to CMs of various degrees of complexity for analysing generalized climate sensitivities and climate response to periodic forcings;
- Analysis of the impact of stochastic perturbations on the statistical properties of the forced and free fluctuations of simplified CMs;
- Study of the climatic tipping points and feedbacks by analysis of the resonances and divergence of the climatic response, and by investigation of the fluctuations of the large scale thermodynamical properties.