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Comparing water, energy and entropy budgets of aquaplanet climate attractors

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The climate system can be seen as a thermal engine that generates entropy by irreversible processes and achieves a steady state by redistributing the input solar energy among its different components (ocean, atmosphere, etc) and by balancing the energy, water mass and entropy budgets over all the spatial scales. Biases in modern climate models are generally related to the fact that their statistical properties are not well represented, giving rise to imperfect closures of the energy cycle. Thus, a proper measurement of the efficiency of the thermal engine in each climate model is needed. Moreover, possible steady states (attractors) that can be approached at climate tipping-points are characterised by different feedbacks becoming dominant in the thermal engine.

We apply the Thermodynamic Diagnostic Tool (*TheDiaTo*) [1] to the attractors recently obtained using the MIT general circulation model (*MITgcm*) in a coupled aquaplanet [2], a planet where the ocean covers the entire globe. Such coupled aquaplanets, where nonlinear interactions between atmosphere, ocean and sea ice are fully taken into account, provide a relevant framework to understand the role of the main feedbacks at play in the climate system. Five attractors have been found, ranging from snowball (where ice covers the entire planet) to hot state conditions (where ice completely disappears) [2].

Using *TheDiaTo*, we analyse the five climate attractors by estimating: a) the energy budgets and meridional energy transports; b) the water mass and latent energy budgets and respective meridional transports; c) the Lorenz Energy Cycle; d) the material entropy production. We consider different coupled atmosphere-ocean-sea ice configurations and cloud parameterizations of *MITgcm* where the energy balance at the top of the atmosphere is progressively better closed in order to understand the occurrence of possible biases in the statistical properties of each attractor.

Our contribution will help clarify the thermodynamic differences in climate attractors and their stability to external perturbations that could shift the climate from a steady state to the other.

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