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Parametric Theory of Climate Change

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A detailed thermodynamic, parametric sensitivity study of the steady state climate system is performed with respect to the solar constant S* and the carbon dioxide concentration of the atmosphere [CO_2]. Using PlaSim, an Earth-like general circulation model of intermediate complexity, S* is modulated between 1160 and 1510 Wm-2 for values of [CO_2] ranging from 90 to 2880 ppm. It is observed that in a wide parameteric range, which includes the present climate conditions, the climate is multistable, i.e. there are two coexisting attractors, one characterised by warm, moist climates (W) and one by completely frozen sea surface (Snowball Earth, SB). For both sets of states, empirical relationships for surface temperature, material entropy production, meridional energy transport, Carnot efficiency and dissipation of kinetic energy are constructed in the parametric plane (S*,[CO_2]). Linear relationships are found for the two transition lines (W→ SB and SB →W) in (S*,[CO_2]) between S* and the logarithm of [CO_2]. The dynamical and thermodynamical properties of W and SB are completely different. W states are dominated by the hydrological cycle and latent heat is prominent in the material entropy production. The SB states are eminently dry climates where heat transport is realized through sensible heat fluxes and entropy mostly generated by dissipation of kinetic energy. It is also shown that the Carnot-like efficiency regularly increases towards each transition between W and SB and that each transition is associated with a large decrease of the Carnot efficiency indicating a restabilisation of the system. Furthermore, it has been found that in SB states, changes in the vertical temperature structure are responsible for the observed changes in the meridional transport.