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Thermodynamical properties of planetary fluid envelopes

Valerio Lucarini (1,2), Klaus Fraedrich (3), and Francesco Ragone (3)

(1) Department of Meteorology, University of Reading, Reading, UK, (2) Department of Mathematics, University of Reading, Reading, UK, (3) Meteorologisches Institut, Klimacampus, University of Hamburg, Hamburg, Germany

In this work we exploit two equivalent formulations of the average rate of material entropy production in a planetary system to propose an approximate splitting between contributions due to vertical and eminently horizontal processes. Our approach is based only upon 2D radiative fields at the surface and at the top of atmosphere of a general planetary body. Using 2D fields at the top of atmosphere alone, we derive lower bounds to the rate of material entropy production and to the intensity of the Lorenz energy cycle. By introducing a measure of the efficiency of the planetary system with respect to horizontal thermodynamical processes, we provide insight on a previous intuition on the possibility of defining a baroclinic heat engine extracting work from the meridional heat flux. The approximate formula of the material entropy production is verified and used for studying the global thermodynamic properties of climate models (CMs) included in the PCMDI/CMIP3 dataset in pre-industrial climate conditions. It is found that about 90% of the material entropy production is due to vertical processes such as convection, whereas the large scale meridional heat transport contributes only about 10%. The total material entropy production is typically 55 mWK-1m-2, with discrepancies of the order of 5% and CMs' baroclinic efficiencies are clustered around 0.055. When looking at the variability and co-variability of the considered thermodynamical quantities, the agreement among CMs is worse, suggesting that the description of feedbacks is more uncertain. Observational estimates of the climatology of the thermodynamical bounds are derived for Earth, Mars, Titan and Venus. We discover that, once a suitable rescaling based upon the energy input is performed, these celestial objects share bounds that agree within one order of magnitude, in spite of the large discrepancies in the atmospheric masses.