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Time and space scale analysis of the climate entropy budget

V. Lucarini (1,2) and S. Pascale (1)

(1) University of Hamburg, Institute of Meteorology, Klimacampus, Hamburg, Germany (valerio.lucarini@zmaw.de, +49-(0)40-428385452), (2) University of Reading, Department of Mathematics and Statistics, Reading, UK

Either in models or in measurements entropy production and fluxes are generally estimated starting from the ratio of temperature and energy fluxes. Given the nonlinearity of the definition of entropy production, this quantities depend on the time and space resolution involved. It is therefore fundamental for observational and theoretical purposes to know how the climate entropy budget is affected by different time-space coarse graining and what are the errors involved when certain time means (e.g. annual) are used in place of others (e.g. daily). Referring to the entropy budget studied in Pascale et al. (2011), we study the effect of combined space and time averaging of the material entropy production (direct and indirect formula), entropy production due to kinetic energy dissipation, hydrological cycle and ocean turbulence. For the time analysis a 50-year run is taken. Time coarse graining shows that material entropy production decreases as the averaging period is increased. Daily cycle and seasonal cycle are the main signals which can be observed. In the indirect formula (based on radiative fields, Goody 2000) an underestimate of 4% and 10% is found associated with neglecting daily and seasonal correlations. The direct formula is less sensitive and shows errors of 2% and 4% respectively and mainly due to response of the hydrological cycle. The material entropy production due to small-scale ocean turbulence shows a sharp decrease ($\sim$ 45%) corresponding to the seasonal cycle and associated with the seasonal thermocline variations. We then take into account also a space coarse graining in which energy fluxes and temperature are re-gridded over space grids of coarser resolution. We find that entropy budget terms decreases when the space resolution is decreased as would be expected from general coarse-graining theory. Our results suggest that the model in consideration, although not designed for dealing with entropy production, behaves consistently with the second law of thermodynamics.