Earth Syst. Dynam. Discuss.,
https://doi.org/10.5194/esd-2020-12-RC1, 2020

Earth System Dynamics
Discussions

Interactive comment on "The Half-order Energy Balance Equation, Part 1: The homogeneous HEBE and long memories" *by* Shaun Lovejoy

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Received and published: 15 June 2020

This is an interesting and innovative manuscript that proposes the appropriate energy balance model that relates heat (S) and surface temperature (T) should involve a half order time derivative of T. It is a half-order energy balance equation (HEBE), a special case of a fractional order energy balance equation (FEBE) rather than the usual full order time derivative traditionally used for box (0D) and Budyko-Sellers (1D) models. The author convincingly argues that it this model is appropriate for longer timescale (10 day or more) variability, both empirically and from physical principles. This has consequences in expecting a longer memory of imposed forcing than one would expect of an integer order EBE; more precisely the response to step forcing has power law rather than exponential decay. The derivation assumes forcing at a conductive-radiative

boundary condition and advection-diffusion of heat a semi-infinite domain: by using a Laplace-Fourier analysis the author obtains an integral form for the surface temperature that can be interpreted as a solution of a fractional differential equation. The case of periodic (annual/diurnal) forcing also considered and the surface thermal impedance is interpreted as a complex climate sensitivity – this is used to account for the observed phase lag between summer maximum forcing and surface maximum temperature.

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