EGU2020-11557
https://doi.org/10.5194/egusphere-egu2020-11557
EGU General Assembly 2020

Correcting Budyko-Sellers boundary conditions: The Half-order Energy Balance Equation (HEBE)

Shaun Lovejoy, Lenin Del Rio Amador, and Roman Procyk
McGill University, Department of Physics, Montreal, Canada (lovejoy@physics.mcgill.ca)

The conventional 1-D energy balance equation (EBE) has no vertical coordinate so that radiative imbalances between the earth and outer space are redirected in the horizontal in an ad hoc manner. We retain the basic EBE but add a vertical coordinate so that the imbalances drive the system by imposing heat fluxes through the surface. While this is theoretically correct, it leads to (apparently) difficult mixed boundary conditions. However, using Babenko's method, we directly obtain simple analytic equations for (2D) surface temperature anomalies $T_s(x,t)$: the Half-order Energy Balance Equation (HEBE) and the Generalized HEBE, (GHEBE) [Lovejoy, 2019a]. The HEBE anomaly equation only depends on the local climate sensitivities and relaxation times. We analytically solve the HEBE and GHEBE for $T_s(x,t)$ and provide evidence that the HEBE applies at scales >≈10km. We also calculate very long time diffusive transport dominated climate states as well as space-time statistics including the cross-correlation matrix needed for empirical orthogonal functions.

The HEBE is the special H = 1/2 case of the Fractional EBE (FEBE) [Lovejoy, 2019b], [Lovejoy, 2019c] and has a long (power law) memory up to its relaxation time t. Several papers have empirically estimated H ≈ 0.5, as well as t ≈ 4 years, whereas the classical zero-dimensional EBE has H = 1 and t ≈ 4 years. The former values permit accurate macroweather forecasts and low uncertainty climate projections; this suggests that the HEBE could apply to time scales as short as a month. Future generalizations include albedo-temperature feedbacks and more realistic treatments of past and future climate states.

References

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