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Nonlocal energy fluxes and fractional operators in updated, stochastic, Budyko-Sellers models

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We introduce a stochastic, energy-balance, climate model defined over the macroweather regime (approximately 15 days or longer). Together, the energy balance principle, combined with the model's natural scaling, demonstrate quite promising results despite the relative simplicity. A special case of the model can also be derived from a very classical basis, and, because of some similarities, we propose this model as a development upon the work of Budyko and Sellers.

When the classical Budyko-Sellers energy balance model is updated by using the (correct) radiative-conductive surface boundary conditions, one obtains the Fractional Energy Balance Equation (FEBE). The FEBE involves fractional space-time operators and its generic solutions are scaling, in agreement with much atmospheric and oceanic data. In time, it implies long range memories that have been successfully used to make both multi-decadal climate projections as well as monthly and seasonal (long range) forecasts. In space, the FEBE is nonlocal so that energy flux imbalances at any location can affect the balance in locations far away. This is possible because the model operates over monthly and longer time scales; over these scales, energy can be both stored and transported in the atmosphere, ocean, and subsurface.

Until now, the FEBE's full nonlocal space-time interaction operator has been only approximated. Here, by introducing a numerical model, the nonlocal dynamics of the FEBE and corresponding Earth-system FEBE energy flows over the 2D Earth surface are fully detailed.

We propose the FEBE as an alternative to more conventional, deterministic, weather-regime-based climate models. Given the generality of the ideas pursued here - the use of fractional operators; the use of stochasticity and the macroweather regime - there seems a great potential for these to be used much more widely. Hopefully this research, and possibly related works, will encourage a greater diversity of pursuits and be inspiring to others in their own work.