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Long-term memory and multifractality of downwelling longwave flux at the Earth's surface

Vasilios Stathopoulos and Christos Matsoukas
University of the Aegean, Department of Environment, Mytilene, Greece (matsoukas@aegean.gr, +30 2251036209)

The Downward Longwave Flux (DLF) is the thermal radiation flux incident at the Earth's surface, emitted by the atmosphere. It is one of the largest components of the radiative budget at the surface, with a planetary average value equal to 342 Wm^{-2}. The study of DLF is very important, due to its large value but also because the effect of greenhouse gases is mainly manifested in this specific radiative component. Modeling DLF is quite complex, because it is sensitive to many climatic quantities, such as the cloud amount, and the atmospheric temperature and humidity profiles, each with its own problems in modeling. Recently, the scientific community has taken an interest in the long-term memory of some climatic quantities, e.g. temperature, finding that it follows a scale-law and thus extending far into the temporal horizon. This finding has been used as a diagnostic tool on the quality of Global Circulation Model (GCM) projections in the future. There are several studies on the memory of temperature, but none so far on DLF, at least in part because it is not measured at as many locations. In this study, we examine the temporal fluctuations of DLF using Multi-Fractal Detrended Fluctuation Analysis (MF-DFA) on a decadal scale. Our dataset is the Baseline Surface Radiation Network (BSRN, http://www.gewex.org/bsrn.html), which records radiation fluxes in a resolution of a few minutes at climatically diverse stations globally since 1992, using very strict quality control guidelines. MF-DFA has been shown to being able not only to quantify the long-term memory characteristics of time series, but also to extract information on the multifractal properties of a process. Our motivation for the investigation of the DLF multifractality is our expectation that it will encompass multifractal properties of all temperature, humidity, and cloud amount, thus giving an all-around statistic of the atmospheric states.

At all of the the 31 examined stations, we find that the timeseries are non-stationary on a scale of a few days. After that point, there is a crossover to DLF showing power-law scaling for time scales of about ten days to five years. Positive correlations are found, with the $h(2)$ exponent for DFA2 having an average value of 0.65 and a standard deviation of 0.15, in close agreement with previous studies in temperature. There is no apparent relationship between $h(2)$ and latitude, station elevation, or proximity to the ocean. In several stations around the equatorial Pacific, we see differentiations in the DLF scaling, presumably due to non-stationarity introduced by the El Niño Southern Oscillation (ENSO). We also find characteristics of multifractality, when we examine the singularity spectrum $f(\alpha) - \alpha$, although again there are distortions in the ENSO geographical area.