Geophysical Research Abstracts
Vol. 15, EGU2013-1491, 2013
EGU General Assembly 2013

A Stochastic Fractional Dynamics Model of Rainfall Statistics

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Rainfall varies in space and time in a highly irregular manner and is described naturally in terms of a stochastic process. A characteristic feature of rainfall statistics is that they depend strongly on the space-time scales over which rain data are averaged. A spectral model of precipitation has been developed based on a stochastic differential equation of fractional order for the point rain rate, that allows a concise description of the second moment statistics of rain at any prescribed space-time averaging scale. The model is designed to faithfully reflect the scale dependence and is thus capable of providing a unified description of the statistics of both radar and rain gauge data. The underlying dynamical equation can be expressed in terms of space-time derivatives of fractional orders that are adjusted together with other model parameters to fit the data. The form of the resulting spectrum gives the model adequate flexibility to capture the subtle interplay between the spatial and temporal scales of variability of rain but strongly constrains the predicted statistical behavior as a function of the averaging length and times scales. The main restriction is the assumption that the statistics of the precipitation field is spatially homogeneous and isotropic and stationary in time. We test the model with radar and gauge data collected contemporaneously at the NASA TRMM ground validation sites located near Melbourne, Florida and in Kwajalein Atoll, Marshall Islands in the tropical Pacific. We estimate the parameters by tuning them to the second moment statistics of the radar data. The model predictions are then found to fit the second moment statistics of the gauge data reasonably well without any further adjustment. Some data sets containing periods of non-stationary behavior that involves occasional anomalously correlated rain events, present a challenge for the model.