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Stochastic disaggregation of daily rainfall into one-hour time scale

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Abstract

The Australian SILO Data Drill facility generates continuous daily rainfall data from 1889 to current date for any set of coordinates on the Australian continent. For the daily rainfall data to have any appeal to users, such as farmers and environmental modellers, a robust disaggregation model that generates sub-daily time series fully consistent with the daily totals while preserving multiple sub-daily time scale stochastic structure is required. A model, which incorporates repetition techniques and a proportional adjusting procedure [Koutsoyiannis, D., Onof, C., 2001. Rainfall disaggregation using adjusting procedures on a Poisson cluster model. J. Hydrol. 246, 109–122] into a regionalised hybrid model [Gyasi-Agyei, Y., 1999. Identification of regional parameters of a stochastic model for rainfall disaggregation. J. Hydrol. 223(3–4), 148–163], has been demonstrated to have such capability. The model is structured such that clusters of consecutive wet days can be disaggregated together during the generation of the binary wet and dry sequence and/ or intensity phases. Two ad hoc remedies to prevent overestimation of the variance and the extreme values, and underestimation of the autocorrelation that could be potentially caused by daily rainfall totals in excess of the hourly maximum have been proposed. The model was evaluated with a 5-year time series of hourly rainfall observed at an erosion control experimental site. All modes of operation of the model reproduced the dry probability very well. Clustering does not seem to affect the dry probability, variance and the intensity-duration–frequency (IFD) curves. The reproduction of the autocorrelations certainly improved with clustering. Capping the hourly rainfall depths to the observed maximum values reproduced near perfect dry probability, variance, autocorrelation and the IFD curves for all months. With this confidence, the 114-year synthetic daily rainfall data set for Rockhampton generated by SILO Data Drill facility was disaggregated to one-hour time scale. The pattern of the results from this data set was identical to that of the observed 5-year data set.

Keywords: Rainfall; Disaggregation; Stochastic process; Regionalisation; Hybrid model

1. Introduction

The Australian SILO Data Drill is a facility for extracting data from an archive of interpolated rainfall and climate surfaces maintained by the Queensland Department of Natural Resources and Mines. These surfaces were constructed by spatially interpolating observational data collected by the Australian Bureau of Meteorology. The Australian Bureau of Meteorology maintains an archive of observational rainfall and climate records that dates back to the mid-1800s.

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Jeffrey et al. (2001), Hutchinson (1995), and Wahba and Wendelberger (1980) have presented the interpolation techniques used to generate the climatic data. Although the SILO Data Drill facility data are all synthetic, they have the advantage of being available for any set of coordinates on the Australian continent, and date back to 1889 (http://www.nrm.qld.gov.au/silo/datadrill/, 29 September, 2003).

For the daily rainfall data to have any appeal to users, such as farmers and environmental modellers developing models at sub-daily time scale, a robust disaggregation model is required. Developed models need to generate sub-daily time series fully consistent with the observed daily totals while preserving the stochastic structure of multiple sub-daily time scales. It is not sufficient for a model to only reproduce the statistics such as mean, variance, autocorrelations and the probability of an interval being dry (referred to as dry probability) at several time scales. The generated rainfall series should also reflect annual trends, in particular for sites that exhibit a clear climate change. Rainfall annual trends exhibiting climate change are typified in Fig. 1 for Rockhampton (longitude 150.50 E and latitude 23.40 S) data generated by SILO Data Drill facility. Because Rockhampton is one of the climatic stations used to develop the database, the synthetic data are, in fact, very close to reality. Disaggregation of such continuous daily rainfall without preserving the individual daily rainfall values may not yield the observed climate change trend. The climate change trend may be regarded as a manifestation of the Hurst phenomenon (Koutsoyiannis, 2003).

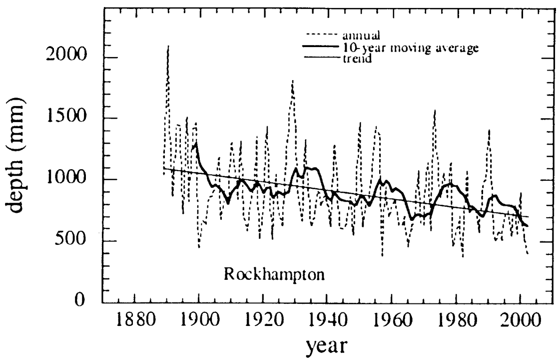

Fig. 1. SILO Data Drill annual rainfall characteristics for Rockhampton.

Bartlett–Lewis and Newman–Scott rectangular pulse models (Rodriguez-Iturbe et al., 1987, 1988) and their variants have been used to disaggregate daily rainfall. Bo et al. (1994) used the modified Bartlett–Lewis model to capture the statistics of finer time scale rainfall from the observed daily rainfall statistics. Their approach involved using daily statistics to estimate the model parameters and then simulate the sequence of rainfall events at any desired time scale. A Bartlett–Lewis based hybrid model (Gyasi-Agyei and Willgoose, 1997, 1999) was regionalised for daily rainfall disaggregation by Gyasi-Agyei (1999). Cowpertwait et al. (1996) presented a fitting procedure for using Newman–Scott model to disaggregate daily rainfall data. Above approaches may not preserve annual trends that may be exhibited by the rainfall data since the individual daily rainfall values are not preserved.

Glasbey et al. (1995) also used the modified Bartlett–Lewis model to disaggregate daily rainfall by conditional simulation. They calibrated the model using statistics of hourly data, without taking into account the seasonality in the data. The model was used to generate an archive of a large number of years of rainfall data. Then, given daily rainfall data, the best matches to sequences of daily totals in the archive, and the hourly data from those past events were used to provide disaggregated sequences. As they pointed out, the disaggregated data were constrained to follow only the same trend in the mean rainfall. Therefore, the model does not necessarily predict the second-order characteristics and the dry probability. Koutsoyiannis and Onof (2001) used a proportional adjusting procedure on a Bartlett–Lewis type model to disaggregate daily rainfall, preserving the individual observed daily totals. Multivariate rainfall disaggregation schemes are discussed in Koutsoyiannis et al. (2003). Cascade-based, fractal and multifractal approaches have also been employed to disaggregate rainfall into finer time scale (e.g. Ormsbee, 1989; Olsson, 1998; Olsson and Berndtsson, 1998; Güntner et al., 2001).

For rainfall data within Central Queensland, Australia, the Bartlett–Lewis models failed to adequately reproduce statistics of the finer time scale, even where these statistics were included in the model parameter calibration. This led to the development of a hybrid model presented in Gyasi-Agyei