Chapter 24


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ABSTRACT

This chapter looks at how interpolated annual and monthly rainfall variation can be improved by developing a geostatistical model that uses remotely-sensed cold cloud duration (CCD) data as a background image for a typical tropical basin, the Rufiji basin in Tanzania. We explored the Kriging model and its variants, and found it to be a good estimator in spatial interpolation mainly due to the inclusion of the non-stationary local mean during estimation. Model parameter sensitivity analysis and residual analysis of errors were used to test model adequacy and performance. They revealed that the parameter values of the variogram namely, the nugget effect, the range, sill value and maximum direction of continuity, as long as they are in acceptable ranges, have low effect on model efficiency and accuracy. Instead interpolation was found to improve when remotely-sensed CCD data was used as a background image as compared to estimation using observed point rainfall data alone. This improvement was revealed in terms of the Nash-Sutcliffe model performance index ($R^2$). Although Kriging model application seems to be data intensive and time consuming in nature, it results in improved spatio-temporal interpolated surfaces so long as interpolated results can be interpreted with confidence and with prudent judgement of the model users.

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INTRODUCTION

One of the factors that determine the quantity of rainfall occurrence in a basin is the distribution and nature of rain-producing clouds in the region. There is interest in the development of a model to reproduce observed rainfall variation in space and time and its relationship with remote-sensing based rain-producing cloud information at a basin level. This is because it would bring greater understanding of atmosphere-ecosystem interaction in a typical tropical climatic region of Africa. More interest is developing to investigate the potential for improvement of rainfall interpolation at a basin scale using the time-series of the cold cloud duration (CCD) data (Grimes & Diop 2003). Several studies (Hill & Donald, 2003; Reynolds et al., 2000; Diallo, et al., 1991; Sannier et al., 1998; Kobayashi & Dye, 2005) show that the link between rainfall and vegetation dynamics in-turn advances our understanding of various crop growth dynamics and agricultural production for large areas.

For the hydroinformatics community adequate and accurate information at a catchment or basin level is required to draw on and integrate principles of hydrodynamics, hydrology, environmental engineering, GIS and remote sensing among others (e.g. Abrahart et al., 2008). Rainfall estimate as one of the main input variables of a hydrologic system, this chapter sees a strong application in solving rainfall-runoff processes as well as in understanding any human-induced and climate-related changes in a basin’s water resources. Accurately estimated areal precipitation through combination of ground based raingauge measurement and remote-sensing based CCD data is an integral part of hydroinformatics that also provides support for decision making at all levels from governance and policy through management to operation, which is an effective means of water management – a challenges faced by governments to implement integrated water resources management at different levels.

Immediate interest of improving rainfall forecasts at a catchment or basin scales is in flood and flood forecasting applications. Mazzetti & Todini (2009) demonstrate a methodological framework and a tool to improve spatial rainfall estimates by combining weather radar and raingauge data for hydrologic applications especially in improving real-time flood forecasting and flood management. Their approach strongly developed in the MUSIC Project (MUSIC Project, 2009). MUSIC is an acronym for Multi-Sensor Precipitation Measurements Integration, Calibration and Flood Forecasting – a project name that was used to represent a project funded by the European Commission funded project under the 5th Framework programme (MUSIC Project, 2009) a summary of which is presented in Mazzetti & Todini (2009).

A wider literature exists on alternative techniques that can be used to eliminate the radar bias through combining radar estimates and raingauges measurements (e.g. Seo and Smith, 1991a,b). The Co-Kriging model is widely used with the aim of eliminating the bias in radar-based rainfall estimates (e.g. Krajewski, 1987; Seo et al., 1990a, b). In more recent development, Todini (2001a,b) introduced a new Block Kriging-Bayesian Combination (BKBC) technique based upon the use of block-Kriging and of Kalman filtering to optimally combine, in a Bayesian sense, areal precipitation fields estimated from meteorological radar to point measurements of precipitation, such as the ones provided by a network of rain-gauges (Mazzetti & Todini, 2009). This approach was adopted to develop a full package known as RAIN-MUSIC, which allows combining together raingages, meteorological radar and satellite rainfall estimates at the different spatial scales (MUSIC Project, 2009; Mazzetti & Todini, 2009).

Although there is a wider coverage of the subject and methodological improvements demonstrated in RAIN-MUSIC package (Mazzetti & Todini, 2009), the authors of this chapter heavily relied on results of a research and modelling exercise conducted using a geostatistical software...
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