Development of a framework for an integrated time-varying agrohydrological forecast system for Southern Africa: Initial results for seasonal forecasts

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Abstract

Uncertainty about hydro-climatic conditions in the immediate future (today), as well as the near (up to one week) and more distant futures (up to one season) remains a fundamental problem challenging decision makers in the fields such as water resources, agriculture, and many other water-sensitive sectors in Southern Africa. Currently many institutions, such as the SA Weather Service, provide weather and climate forecasts with lead times ranging from 1 d to one season. However, disconnects exist between the weather/climate forecasts and their links to agrohydrological models, and in the applications of forecast information for targeted agricultural and water-related decision-making. The skills level of the current weather and climate forecasts, and the mismatch in scales between the output from weather/climate models and the spatial scales at which hydrological models are applied, as well as the format of seasonal forecasts in that they cannot be used directly in agrohydrological models, are some of the problems identified in this study and are being addressed. This has necessitated the development of a GIS-based framework in which the 'translation' of weather and climate forecasts into more tangible agrohydrological forecasts such as streamflows, reservoir levels or crop yields is facilitated for all the inter-linked quaternary catchments for enhanced economic, environmental and societal decision making over South Africa in general, and in selected catchments in particular. For monthly and seasonal (i.e. 3-month lead time) forecasts, two methods, viz. the Historical Sequence Method and the Ensemble Re-Ordering Method have been developed to translate the triplet of forecast rainfall probabilities (i.e. above, near and below normal) into daily quantitative values of rainfall for use in hydrological models. The first method was applied together with the daily time step ACRU Model to simulate seasonal flow forecasts in the Mgeni catchment in KwaZulu-Natal, South Africa. In taking account of uncertainty in the seasonal rainfall forecasts through the process of translating these to daily streamflow simulations by the ACRU Model, some skilful initial forecasts of streamflows can be obtained which can assist decision makers to take protective action against the impacts of hydro-climatic variability.

Keywords: GIS-based framework, translation of rainfall forecasts, ACRU Model, streamflow forecasting

Introduction

Uncertainties about future climatic conditions create major risks to not only natural resources such as water, agriculture, forestry or to fisheries, but also to other climate-sensitive sectors which include traffic, energy, city planning and environmental protection. Agriculture and water resources are, however, considered as the most weather- and climate-dependent of all human activities (Hansen, 2002; Maini et al., 2004). The marked intra-seasonal and inter-annual variability of climate over Southern Africa has induced a high-risk environment for decision takers in water resources and agriculture because these variabilities affect the major inputs to the hydrological system and certain processes within it (Kunz, 1993; Schulze, 1997). Hence, water resource managers and agriculturalists in Southern Africa need to be advised of likely climatic and hydrological conditions well in advance by producing skilful hydro-climatic forecasts that have the potential to reduce risk in the near and long term, and to provide valuable support to meet the increasing and competing demands for limited water resources. In South Africa, many institutions such as the South African Weather Service (SAWS), the University of Pretoria and the University of Cape Town have been actively involved in providing short- (1 to 3 d) and medium- (4 to 14 d), as well as long-term (up to 6 months) rainfall forecasts across a range of space scales. Some of these forecasts (e.g. SAWS seasonal forecasts) for Southern Africa have been shown to possess certain levels of skills when they are compared against observations (Klopper and Landman, 2003). The challenge, however, still lies in the improvement of spatial and temporal resolution of the weather and climate forecasts, and the translation of these forecasts into suitable scales and forms that are required by agrohydrological models. These challenges must be addressed if hydrological and/or crop-yield models are to contribute to the task of transformation of weather/climate forecasts into more tangible attributes such as streamflows, reservoir levels, irrigation requirements, soil water content, and crop yields. A general description of a GIS-based framework developed in this study is given in the next section, followed by a brief description of the ACRU Model (Schulze, 1995) for streamflow simulations. An evaluation of one method of temporal downscaling of categorical seasonal forecasts is then presented in order to demonstrate its potential usefulness. Finally, concluding remarks are provided. The research described in

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Received 10 September 2007; accepted in revised form 11 April 2008.

this paper forms part of a Water Research Commission-funded project on the development of an agrohydrological forecast system for South Africa, and reports on developments at the end of 18 months into a 5-year project.

A GIS-based framework

Owing to the complexity and iterative calculations of the translation process from climate to agrohydrological forecasts, manual calculations and data extractions are out of the question. A geographic information system (GIS)-based framework, therefore, becomes a very important platform for gathering, filtering, translating and generating information that can be used directly with agrohydrological models for an effective agrohydrological forecasting system. Within this framework, GIS organises spatial information, provides techniques for pre-processing data (including spatial disaggregation), provides data structure and format conversion and displays post-processed information through reformatting, tabulation, mapping and report generation. A schematic flow chart demonstrating the structure of the GIS-based framework for the agrohydrological forecasting facility being developed in this project is provided by Fig. 1. Based on the framework, a GIS-based computer program has been developed using the Visual Basic programming language that links to the GIS and processes all the calculations required to translate the multi-day, monthly and/or to seasonal climate forecasts into daily quantitative values suitable for application with daily time-step hydrological or crop-yield models. The program runs on the Windows operating system. Once the program is initiated, the user has options to select the forecast types in the main window (Fig. 2). In its present state the program is designed to operate at the spatial scale of quaternary catchments (QCs) into which South Africa has been delineated by the Department of Water Affairs and Forestry (DWAF) for operational decision making, and the program has 3 major components, viz. near-real time observations derived from radar, satellite and daily reporting weather stations, short (up to 4 d) and medium term (up to 14 d), as well as long-term (up to 3 months) forecasts from various numerical weather prediction (NWP) and climate models.

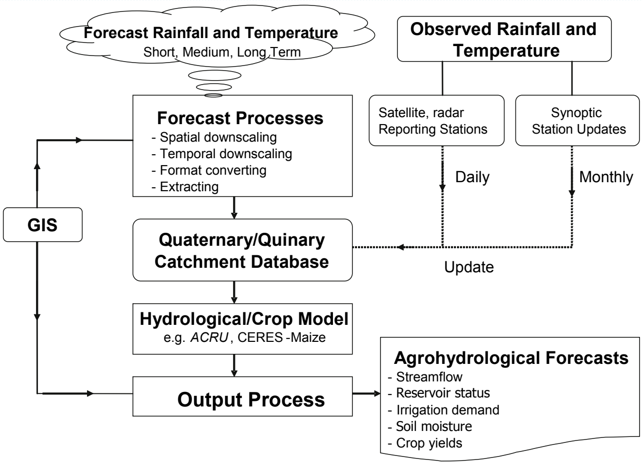

Figure 1
A schematic flow chart demonstrating the structure of the agrohydrological forecasting framework

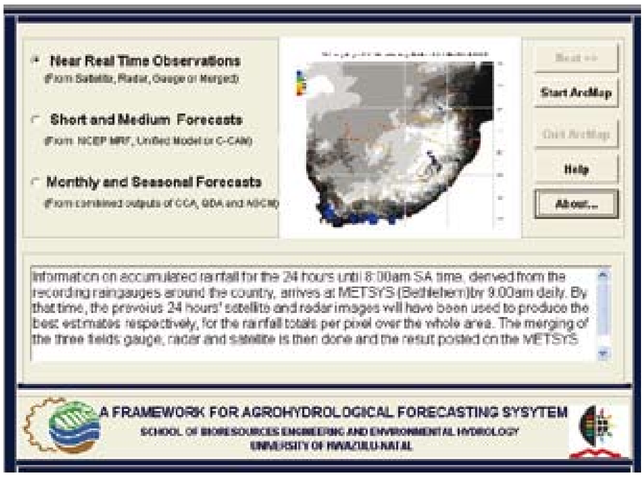

Figure 2
The main window showing options for near-real time, short- and medium-, as well as long-range forecasting in the GIS-based framework for agrohydrological forecasting system (as of mid-2007)

Near-real time estimates of precipitation derived from satellite, radar and rain-gauge data

The METSYS group of SAWS and their collaborators a few years ago launched a project called **S**patial **I**nterpolation and **M**apping of **R**ainfall (SIMAR) that aimed at developing a near-real time, spatially high resolution rainfall measuring and mapping system for southern Africa, based on both the surface raingauge networks and remote sensing techniques. Daily individual and merged rainfall maps from these data sources are now available on a daily basis at a spatial resolution of ~1.7 km, for the entire Southern African subcontinent (Deyzel et al., 2004; Kroese, 2004; Pegram, 2004). The incorporation of these products into the framework of an agrohydrological forecasting system is of fundamental importance for many applications in agrohydrology. Their availability in near-real time is a vital input in simulating the ‘now state’ (i.e. of ‘this morning’) of various hydrological fluxes and states such as effective rainfalls, soil moisture contents, streamflows (made up of stormflow and baseflow components), groundwater recharge and reservoir levels on a daily basis. This, in turn, has the potential to improve the accuracy of near-real time agrohydrological forecasts that provide guidance to decision makers in agriculture and water management, as well as to disaster managers issuing flood forecasts and warnings. An algorithm has been developed within the framework to downscale these rainfall fields to a particular location of interest (e.g. QC) and convert them into formatted rainfall input files for the ACRU Model.

Short- and medium-range forecasts from weather prediction models

SAWS is currently employing the Unified Model (UM) for short-range weather forecasts (up to 2 d) and the National Centre for Environmental Prediction for Medium Range Forecasting (NCEP-MRF) Model for medium and extended range forecasts (up to 14 d) across Southern Africa. The rainfall forecasts from these 2 models and the forecasts issued by the University of Pretoria (UP) using the Conformal-Cubic Atmospheric Model (C-CAM) have, to date, been incorporated in the framework for short- and medium-range agrohydrological forecasting systems (Fig. 3). The resolution, uncertainty and ensemble selection, as well as the procedures constructed to convert these forecasts into suitable form have been addressed in this research.

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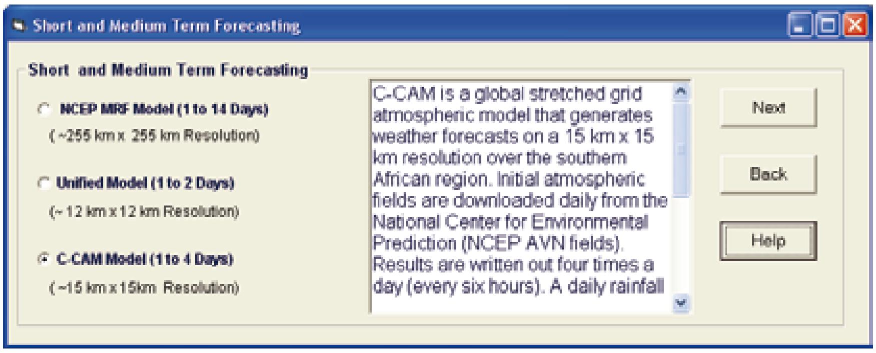

Figure 3
A screen showing the short-range and medium forecasting model options available (as of mid-2007)

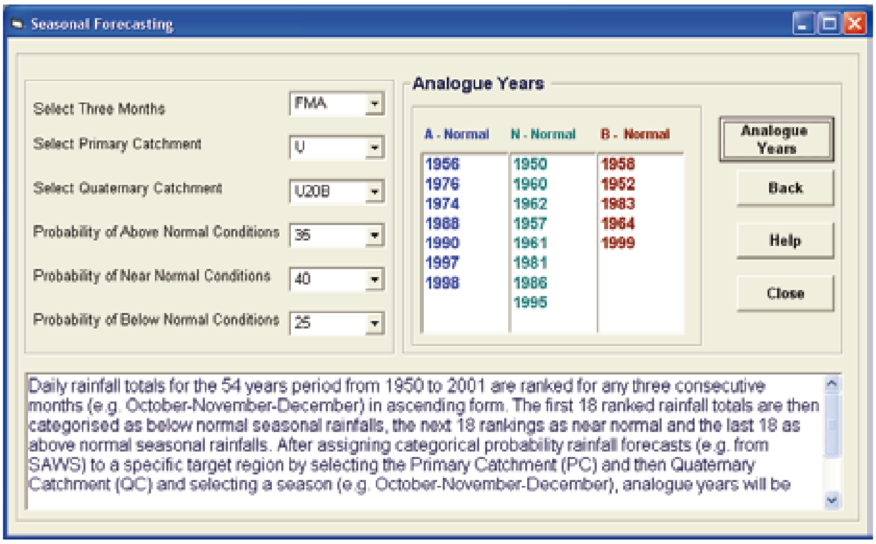

Figure 4
A window showing the translation of categorical rainfall forecasts into daily time-series values based on the analogue method

Categorical monthly and seasonal forecasts from climate models

In Southern Africa, monthly and seasonal (3 to 6 months) hydro-climatic forecasts are frequently required by different sectors of society as the region is severely affected by drought and floods. Among the various sectors, water resources and agriculture can obviously benefit considerably from such forecasts. SAWS has been producing seasonal forecasts in 3 equi-probable categories of below-, near- and above-normal rainfalls for monthly and 3 consecutive months. These forecasts are available routinely on the SAWS website. However, production of seasonal climate forecasts in itself will not be enough for operational hydrological and agricultural decision making. Often in operational agrohydrological services, there is a need to estimate the consequences of seasonal climate forecasts with respect to agrohydrological variables that are closer to the actual problems faced by society such as streamflow amounts, reservoir levels, soil moisture contents and crop yield estimates. Hence, development of generic methodologies for temporal downscaling of categorical seasonal forecasts into a daily time series of values suitable for agrohydrological models becomes vital. Basically, weather generators and analogue methods are the most widely used methods for generating time series data that can be used as input to agrohydrological models. The temporal downscaling method developed in this framework uses both the analogue and weather generator approaches. The analogue method used in this framework is based on ranking of historical rainfall records, and analogue years are selected randomly, conditioned by the probability assigned to each category. Each category is weighted, based on the level of the confidence in the forecast. The higher the assigned probability of a category of rainfall, the higher the number of analogue years will be sampled from that particular category. To generate the daily rainfall values representing the selected forecast season from each of the selected analogue years, 2 methods have been adopted, viz. the Historical Sequence Method and the Ensemble Re-Ordering Method. The Historical Sequence Method is based on the assumption that 'daily rainfall values within the forecast season develop in similar sequences developed in the selected analogue years representing each category'. This approach provides one possible realisation of the past climate which is likely to occur in the future and attempts to preserve the historical temporal persistence of the past weather conditions occurred in the selected analogue years. The Ensemble Re-Ordering Method was introduced by Clark et al. (2004) and uses random chance as the determining factor for an observation to be included in the sample that represents the forecast day. In this respect, the ensembles used to populate the sequences are randomly selected from a mix of different dates of all historical years or from a subset of preferentially selected years. For each forecast day, the ensemble members are re-ordered so as to preserve the spatio-temporal variability in the historical records. An algorithm has been coded within the framework that enables the processing of all the steps required for conditioning the random selection of analogue years on the probability assigned to each category (Fig. 4). Moreover, the program has been designed to automatically extract daily data sets that represent estimates of future conditions for the targeted forecast season based on the Historical Sequence and Ensemble Re-Ordering Methods (Fig. 5). The following steps are contained in the algorithm and are applicable to both the monthly and seasonal (3 months) categorical climate forecasts:

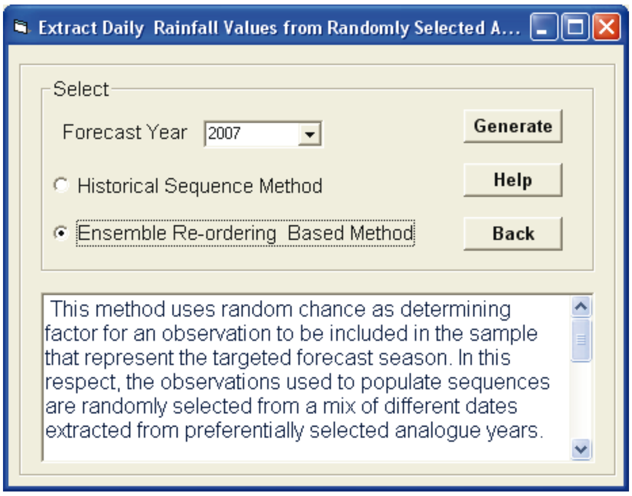

Figure 5
A window showing options for extracting daily rainfall values from randomly selected analogue years

Ranking of daily rainfall totals into below-, near- and above-normal categories

Quality checked daily rainfall totals for the 54-year period from 1950 to 2003 are ranked for monthly and any 3 consecutive months (e.g. October-November-December) in an ascending (lowest to highest) order. The first 18 ranked rainfall totals out of the 54 are then categorised as representing 'below-normal' seasonal rainfalls, the next 18 rankings as 'near-normal' and the highest 18 as 'above-normal' seasonal rainfalls.

Assigning inputs and selecting analogue years

First, a season (e.g. October-November-December), the primary catchment (PC) within South Africa and the quaternary catchment (QC) of interest within that primary catchment, as well as categorical probability rainfall forecasts obtained from various institutions (e.g. from SAWS) are selected from their respective drop-down menus (Fig. 4). Then analogue years are randomly sampled, based on the probability assigned to each category. Since probabilities of categorical climate forecasts are given in multiples of 5 percentiles, the analogue years that represent each category are obtained by dividing the probability forecast by 5. In each run, therefore, 20 analogue years in total will be selected to represent the probability assigned to the 3 categories (Fig. 4). For example, if for each of the 3 categories the forecast probabilities of above-, near- and below-normal rainfall were 35%, 40% and 25% (as in Fig. 4), the respective number of analogue years selected would be 7, 8 and 5.

Extracting daily rainfall values from selected analogue years

Daily rainfall values representing the selected forecast season can then be extracted based on either the Historical Sequence Method or the Ensemble Re-Ordering Method (Fig. 5). If the Historical Sequence Method is selected (Fig. 5), 20 independent daily rainfall files from each of the analogue years will be generated. Each file has daily data sets extracted from the same dates in the historical records of the analogue years, and these files are then automatically used as the daily rainfall files for agrohydrological models. If the Ensemble Re-Ordering Method is chosen (Fig. 5), the daily rainfall values from each of the selected analogue years for the target season are collected in a temporal array. The program then randomly re-samples 10 ensemble members for each forecast day of a given season from a mix of dates in the temporal array. Another random selection of dates from all historical years (1950 to 2003) of the same season is then used to re-order the temporal correlation structure of the ensembles selected from the preferentially selected analogue years. The random selection of dates from the historical records is only used for the first forecast day, and is persisted for the subsequent forecast lead times. The re-ordered ensemble members can then be used as inputs into agrohydrological models. The concepts contained in the Ensemble Re-Ordering Method are described more fully and quantitatively in Clark et al. (2004).

The main objective of developing a framework is to facilitate the translation of state-of-the-art weather and climate forecasts into suitable quantitative values which can be input into the daily time step hydrological and crop models. Once the translation process is completed, the subsequent step is the generation of agrohydrologically related forecasts (e.g. streamflows, reservoir levels, crop yields). For this purpose, the ACRU agrohydrological modelling system (Schulze, 1995 and updates) is employed in this study to generate agrohydrological forecasts. A short summary of the ACRU Model is presented in the section which follows.

The ACRU Agrohydrological Model

ACRU is a daily time step, multi-purpose and multi-level conceptual-physical agrohydrological simulation model. As a conceptual-physical water budget model, ACRU (Schulze, 1995 and updates) integrates various water budgeting, runoff producing components of the terrestrial hydrological system and operational aspects of water resource management with risk analysis (Schulze, 1995; Smithers and Schulze, 1995; Schulze and Smithers, 2004). The model was designed as two-layer soil-water budgeting model which has been structured to be sensitive to land-use changes on soil moisture, evaporative rates and runoff regimes. The model has been considerably updated from original versions to its present status (Schulze and Smithers, 2004) in order to simulate those components and processes of the hydrological cycle which are affected by the soil-water budget, such as stormflow, baseflow, irrigation demand, sediment yield or crop yield, and to output any of those components on a daily basis (where relevant), or as monthly and annual totals of the daily values. The ACRU Model was selected for this study because it has been widely verified under highly varying hydrological regimes on gauged catchments in Southern Africa (cf. reviews by Schulze, 1995; Schulze and Smithers, 2004) and elsewhere in the world (e.g. Dunsmore et al., 1986; Ghile, 2004). Furthermore, for Southern Africa, ACRU is linked to extensive databases containing quality controlled daily rainfall, minimum and maximum temperatures for the period of 1950 to 2000 as well as to baseline land cover and soil information for each of the 1 946 hydrologically interlinked quaternary catchments (QCs) that make up Southern Africa (Schulze, 2006). The linking of the ACRU Model to the databases is known as the quaternary catchments database, or QCD.

Testing the historical sequence downscaling method

As was described briefly above, two approaches, viz. the Historical Sequence Method and the Ensemble Re-Ordering Method,

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ISSN 0378-4738 = Water SA Vol. 34 No. 3 July 2008
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have been developed in this study in order to generate daily rainfall values from preferentially selected analogue years, for subsequent use as input into hydrological/crop models. If these approaches are to be applicable with a high degree of confidence, they should be evaluated in various parts of Southern Africa. This paper focuses on the evaluation of the first method, using the Mgeni catchment in KwaZulu-Natal as the case study area (Fig. 6).

The Mgeni catchment

The Mgeni catchment with an area of 4 469 km^2 is home to over 5 m. people in the Durban-Pietermaritzburg metropolitan area and produces approximately 20% of South Africa's gross national product (Schäfer and Van Rooyen, 1993) from only 0.35% of the country's area. It is one of the South Africa's tertiary level catchments which have been delineated by the Department of Water Affairs and Forestry (DWAF). The Mgeni catchment is characterised by high spatial and temporal variability of rainfalls and streamflows and is subjected to periodic droughts and heavy flooding (Schulze, 1997; Schulze and Perks, 2000). Rainfall is strongly seasonal and varies from 680 mm/a near the coast to 1 200 mm/a in the more rugged western parts of the Mgeni catchment, with 80% of the inland rainfall occurring largely as convective storms in the summer months (October to March) while along the coast lower-intensity general rains in summer make up 65 to 70% of annual total (Schulze et al., 2004). Research conducted by Schulze (1997) has indicated that the coefficient of variation (CoV%) of annual rainfall over the Mgeni catchment ranges between 25 and 30%, while that of the annual runoff is between 50 and 100%. The ratio of the conversion of mean annual rainfall to mean catchment runoff is 18%. Climatically the Mgeni catchment is classified as a sub-humid zone (e.g. Van Zyl, 2003). However, considering the strong rainfall seasonality, low rainfall to runoff conversion and high ratio of annual evaporative demand, a considerable area of the Mgeni catchment may be regarded as hydrologically semi-arid (Schulze, 1997).

Data used

The categorical seasonal rainfall forecasts used in this study were obtained from SAWS, which has been producing seasonal rainfall forecasts in the 3 equi-probable categories of below-normal, near-normal and above-normal rainfalls for one month and for any consecutive 3 months, i.e. seasonal. This paper focuses on the seasonal forecasts and investigates the skill of retrospective forecasts for the three consecutive months of October-November-December (OND), November-December-January (NDJ), December-January-February (DJF) and January-February-March (JFM) from October 2003 to March 2006, because the period October to March makes up the main rainfall months in this Southern Hemisphere summer rainfall region. The forecasts were produced at the beginning of each season, referred to as a 'zero' month lead-time. Wide ranging spatial variability within the Mgeni catchment with regard to its climate, soils and land uses made it necessary to apply the ACRU simulations in semi-distributed catchment mode in order to simulate also accumulated streamflows from subcatchments cascading downstream at the exit of each Quaternary Catchment (QC). The ACRU Model was run with historical observed daily rainfall from year 2000 to the beginning of the forecast period in order to create representative antecedent conditions and initialise stores (e.g. soil moisture status in the top- and subsoil, baseflow store and releases). The Historical Sequence Method was then applied for the 12 QCs that make up the Mgeni catchment for the 3-month period OND, NDJ, DJF and JFM from October 2003 to March 2006. The outputs of the ACRU Model derived using the Historical Sequence Method from seasonal rainfall forecasts were evaluated against corresponding reference streamflows generated by the ACRU Model from gauged rainfall and assuming a baseline land cover. Observed streamflows were not used in this study owing to the lack of data describing the daily abstractions and releases from the large dams, as well as return flows and inter-catchment transfers within the Mgeni catchment. It is important to bear in mind that wherever the term 'observed streamflows' is used in this paper, they are in fact simulated streamflows with the ACRU Model, but using the observed rainfalls.

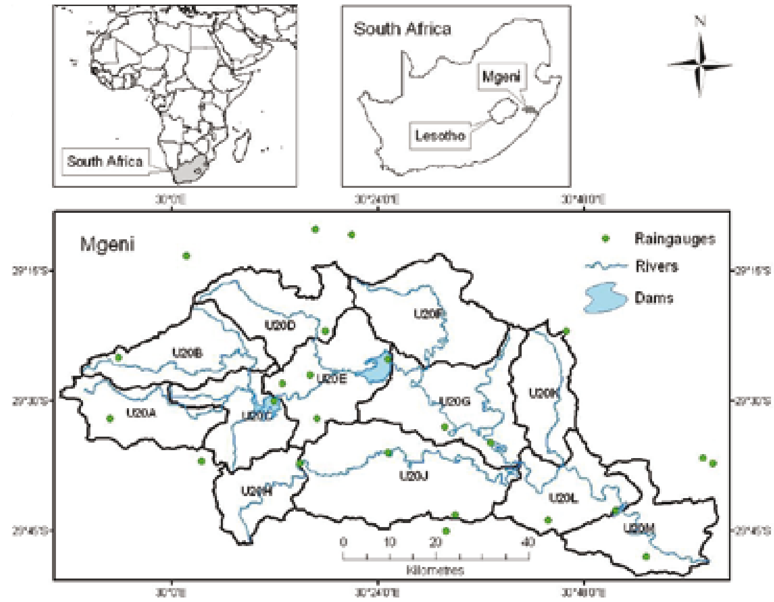

Figure 6
Overview of the Mgeni and its subcatchments

Results and discussion

For this initial study, a variety of statistical measures has been applied to assess the skill of the Historical Sequence Method. For reasons of space, however, only box-and-whisker plots, correlation coefficients (R^2), biases, relative mean square errors (RMSE), relative mean absolute errors (MAE) and cumulative density function (CDF) are presented in this paper. Figure 7 shows box-and-whisker plots of the generated mean (a), standard deviation (b), skewness (c) and coefficient of variation (d) from 20 ensembles of streamflows for the OND, NDJ, DJF and JFM of the 2003-2004 rainy season at the mouth of the Mgeni catchment. A box-and-whisker in each box plot indicates the lower extreme, lower quartile (the 25th percentile), median (i.e. the line across the box), mean (x signs) upper quartile (the 75th percentile) and upper extreme of the forecast streamflow sequences. The observed mean, standard deviation, skewness and coefficient of variation are depicted as diamonds, with circles indicating the values outside of the simulated range. In general, if the statistics of observed data lie within the box of simulated values, it suggests that the simulated values have reproduced the statistics of the observed data adequately. The statistical moments

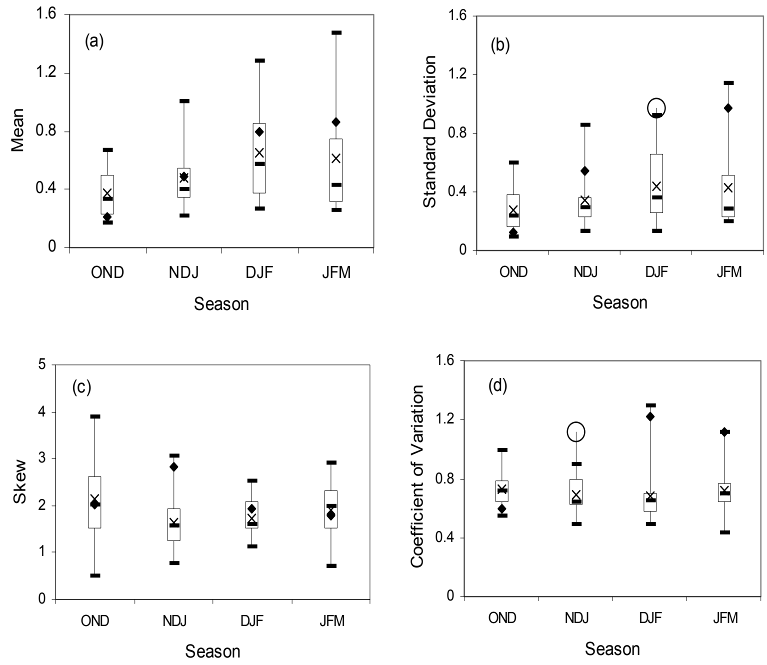

Figure 7
Box plots of statistics of generated streamflows derived from the Historical Sequence Method along with the observed values at the mouth of the Mgeni catchment for OND, NDJ, DJF and JFM of 2003/2004. The box-and-whiskers represent the minimum, lower quartile, median, upper quartile and maximum of the forecasted streamflow sequences, while the x signs represent the simulated mean values. Diamonds represent the observed values, with circles indicating the values outside the simulated range.

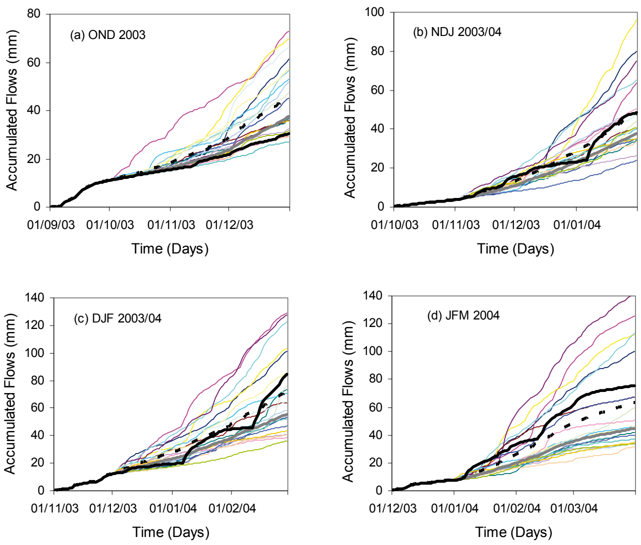

Figure 8
Forecast vs. observed seasonal accumulated flows at the mouth of the Mgeni catchment for OND (a), NDJ (b), DJF (c) and JFM (d) of 2003/04, using the Historical Sequence Method, with the thick black solid line representing the observed accumulated streamflow, and the thick grey solid and dashed lines representing the forecasted accumulated median and average flows, respectively.

shown in Fig. 7 generally illustrate that the observed streamflow statistics are well simulated within the range of the four quartiles, except for NDJ and DJF where the coefficient of variation and the standard deviation exceeded the upper extremes respectively. The observed means and skewness are well reproduced by the simulations. However, except for OND, the standard deviations and coefficient of variations are slightly under-estimated, suggesting that the observed dispersion (spread-out) is not as well simulated as desired.

To extend the analysis, ensembles of accumulated daily flows were computed at the Mgeni catchment outlet at the beginning of each season using the Historical Sequence Method (Fig. 8). From these ensembles of forecasts, the mean and median are computed as the 'best' estimates that can be used to help agricultural and water managers in their decision making. Visually, the accumulated average streamflow values are much closer to the actual accumulated streamflow values than the accumulated median values for the selected seasons, except for the OND season. Correlation coefficients (R^2), biases, relative mean square errors (RMSE) and relative mean absolute errors (MAE) were computed in order to assess the accuracy of averaged cumulative forecast flows against their corresponding cumulative observed flows. Table 1 reveals a very high performance of the Historical Sequence Method, with $R^2 > 0.95$ in all selected seasons. The correlation coefficient is especially strong for OND ($R^2 = 0.99$), but appears to be slightly biased (5.49), indicating a slight over-estimation over the accumulated observed flows. For NDJ, the MAE (1.83) and bias (-0.08) are small, revealing that the accumulated average streamflows have mimicked the corresponding observed accumulated flows excellently. Statistics for DJF also show good relationships between the forecast and observed, albeit with a slight systematic bias. Although the correlation coefficient is high for the JFM period, substantial biases, RMSEs and MAEs were found, indicating significant systematic error in the forecast. The negative bias indicates that the averaged cumulative forecasts were consistently below their corresponding cumulative observed flows (Table 1).

Another important technique to help visualize the cumulative probability distribution is the cumulative density function, CDF (Fig. 9). The cumulative probability is constructed from the generated accumulated average streamflows from forecasts and the actual accumulated streamflow values from observed rainfalls in Fig. 8. As is expected from the results in Table 1, the forecast cumulative probability for NDJ mirrored the corresponding the cumulative probability of observed accumulated streamflows well. For OND and DJF, the cumulative probability distribution is biased slightly on the wetter side, while the cumulative probability distribution for JFM is significantly drier than the corresponding observed cumulative distribution, especially

TABLE 1
Statistics of performance of the Historical Sequence Method for OND, NDJ, DJF and JFM of 2003/2004 at the mouth of the Mgeni catchment

Statistics	OND 2003	NDJ 2003/04	DJF 2003/04	JFM 2004
R^2	0.99	0.96	0.95	0.97
Bias	5.46	-0.08	2.28	-14.78
RMSE	7.06	2.46	5.57	17.76
MAE	5.46	1.83	4.60	14.86

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ISSN 0378-4738 = Water SA Vol. 34 No. 3 July 2008
ISSN 1816-7950 = Water SA (on-line)

for the higher streamflow values. As may be seen in Fig. 9 (d), for accumulated streamflows of less than or equal to 50 mm, the cumulative probability is 84% with the rainfall forecasts, but with the same cumulative probability there is a chance of getting less than or equal to 65 mm of accumulated streamflows from the rainfall observation.

Summary and conclusions

The development of effective procedures for the use of weather and climate forecasts into forecasts of various agrohydrological variables (e.g. streamflows, soil moisture, crop yields) plays a prominent role in operational decision-making in the agriculture and water sectors. For this purpose, a GIS-based framework is being developed in a Water Research Commission-funded project to serve as an aid to process all the computations required to translate the daily to seasonal climate forecasts into daily quantitative values suitable for application with hydrological or crop models. The framework is being designed to include generic windows which allow users to process the near real-time rainfall fields estimated by remotely sensed tools as well as forecasts of weather/climate models into suitable scales and formats that are needed by many daily time step agrohydrological models. The key features of the framework are that it:

- Facilitates the selection of near-real time remotely sensed observations, as well as short-, medium- and longer-term forecasts supplied by various weather and climate models from different institutions across a range of time scales
- Links these to comprehensive GIS functionality that provides tools for spatial disaggregation, data structure and reformatting as well as for post-processing of data/information through tabulation, mapping and report generation
- Translates categorical monthly and seasonal forecasts into a daily time series of values suitable for agrohydrological models through generic algorithms developed within the framework
- Converts ensembles of rainfall forecasts into suitable formats which are understood by the GIS
- Downscales grid layers to quaternary catchments
- Finally, extracts rainfall data to ACRU-formatted text input files.

The development of the framework is an ongoing process and will continue in research phase up to 2010 in order to incorporate other weather variables and forecast products issued by various institutions. An important component of the framework is the translation of the categorical monthly and seasonal rainfall forecasts into daily quantitative values, as such a triplet of probabilities (i.e. above, near and below normal) cannot be applied in a hydrological/crop model which operates on a daily time step in their original published form. Two approaches, viz. the Historical Sequence Method and the Ensemble Re-Ordering Method have been developed to translate the triplet of probabilities into daily quantitative values. The first approach is designed to sample daily rainfall values from the same dates in selected analogue years, while the second alternative randomly generates ensembles of 10 members from selected analogue years for each forecast day, and uses the Ensemble Re-Ordering Method (Clark et al., 2004) as a post-processing step to reconstruct the temporal persistence of the synthetically

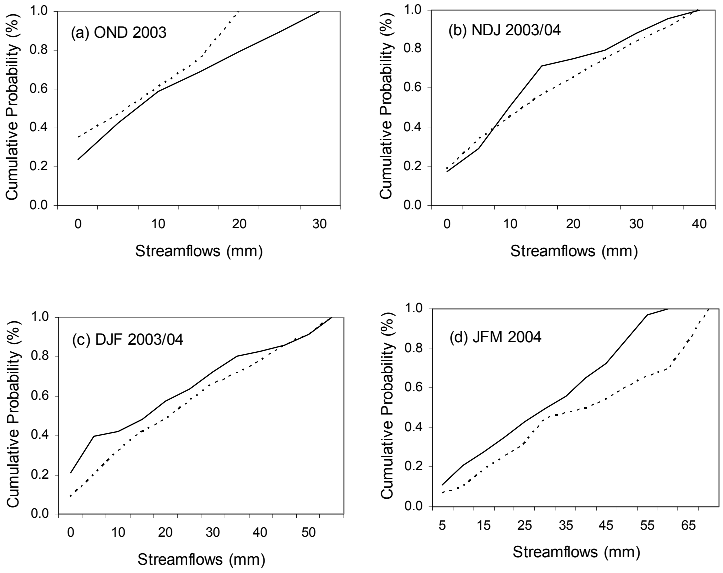

Figure 9
Cumulative probability of daily flows simulated with the ACRU Model vs. observed flows at the mouth of the Mgeni catchment for OND (a), NDJ (b), DJF (c) and JFM (d) of 2003/04, with the solid line representing the observed cumulative probability, and the dashed lines representing the forecasted cumulative probability

generated daily rainfall data. In this paper on initial results, ensembles of simulated rainfalls derived using the Historical Sequence Method were used as input into the ACRU Model to generate an ensemble of simulated streamflows at seasonal time scales in the Mgeni catchment. Reasonably good results were obtained for most of the selected seasons. These initial results reflect the assumption that the daily rainfalls during the forecast period could mirror those of the selected analogue years for the same calendar period. The Historical Sequence Method is conceptually simple. Nevertheless, it can be used with confidence to translate the skilful categorical rainfall forecasts into daily quantitative values which are useful for various agrohydrological applications in South Africa and possibly elsewhere.

Acknowledgements

This study is being undertaken as part of the Water Research Commission (WRC) funded project K5/1646 titled '**Applications of Rainfall Forecasts for Agriculturally Related Decision Making in Selected Catchments.'** The authors would like to express their gratitude to the collaborating institutions in the project, viz. the South African Weather Service, the University of Pretoria, the Agricultural Research Council, the University of Cape Town, and the University of the Free State for their inputs.

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Available on website http://www.wrc.org.za
ISSN 0378-4738 = Water SA Vol. 34 No. 3 July 2008
ISSN 1816-7950 = Water SA (on-line)