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SIMULATION OF PRECIPITATION FIELDS IN SPACE AND TIME FROM PROBABILISTIC QUANTITATIVE PRECIPITATION FORECAST

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1. INTRODUCTION

As a part of the National Weather Service Eastern Region's (NWS/ER) Probabilistic Quantitative Precipitation Forecast/Probabilistic River Stage Forecast (PQPF/PRSF) Project, NWS Hydrologic Research Laboratory (HRL) is developing the Ensemble Precipitation Processor (EPP): it 1) inputs Weather Forecast Office (WFO)-produced and River Forecast Center (RFC)-mosaicked gridded field of PQPF for 24-hr mean areal (i.e., spatially averaged) precipitation (MAP), and 2) produces multiple traces of 'plausible' four 6-hr precipitation fields on the HRAP grid (approximately 4x4 km^2 in mid-latitudes). The spatial scale of PQPF is expected to be between a thousand to several thousand square kilometers. The purpose of this paper is to describe one of a number of approaches being pursued for PQPF-based simulation of space-time precipitation fields in EPP.

2. CONDITIONAL SIMULATION OF PRECIPITATION FIELDS

Spatial simulation of 0-6 hr precipitation fields is based on Seo (1997a) as applied in the conditional simulation mode (Deutsch and Journel 1992): 1) the precipitation area is first simulated via indicator kriging and then 2) precipitation amounts over the precipitation area are simulated via optimal linear estimation under an assumed marginal probability distribution function for 6-hr precipitation (e.g., two-parameter Weibull). Spatial patterns of precipitation area and precipitation amount over the precipitation area are controlled by the indicator and conditional correlation functions (e.g., exponential), respectively.

Space-time simulation for the subsequent time intervals is based on Seo (1997b) as applied in the conditional simulation mode: temporal dependences of precipitation/no-precipitation and precipitation amount given precipitation are assumed to be Markovian in the Lagrangean domain.

3. TEMPORAL DOWN-SCALING OF PQPF

PQPF, as expected to be experimentally produced at selected WFOs in ER (Kyzysztofowicz and Sigrest 1997, Kyzysztofowicz and Pomroy 1997), consists of the following variables; $Pr[W>0]$, $E[W \mid W>0]$, $Var[W \mid W>0]$, and $E[w_k/W \mid W>0]$, k=1,2,3,4, where W and w_k denote the 24-hr MAP and the 6-hr MAP for the k-th time interval in the 24-hr duration, respectively. For the sake of notational brevity, dependence of the variables on location in the PQPF grid is not denoted explicitly.

In order to simulate traces of four 6-hr precipitation fields on the HRAP grid, which cover the first 24 hrs of precipitation forecast, the conditional simulation procedure requires that the following parameters be known; $p_k \equiv Pr[R_{u,k}>0]$, $m_k \equiv E[R_k(u) \mid R_k(u)>0]$, and $\sigma_k^2 \equiv Var[R_k(u) \mid R_k(u)>0]$, k=1,2,3,4, where $R_k(u)$ is the 6-hr precipitation, resolvable at the HRAP scale, at location u in the parent PQPF grid box at the k-th time interval. Under the assumption that precipitation is locally homogeneous, the parameters are not location-dependent (i.e., uniform) within the parent PQPF grid box.

Complete specification of p_k, m_k and σ_k^2 based solely on PQPF is not possible. In this work, we 1) estimate p_k and m_k from a combination of PQPF and climatology, and 2) obtain σ_k^2 by specifying the conditional coefficient of variation, $cv_k \equiv \sigma_k/m_k$, outright from climatology. Seemingly an oversimplification, the latter is well supported empirically as will be reported elsewhere in detail. To carry out the former, we first estimate $Pr[w_k>0]$ and $E[w_k \mid w_k>0]$ from PQPF as follows:

$$Pr[w_k=0]=Pr[w_k/W=0 \mid W>0]Pr[W>0]+Pr[W=0]$$

$$\begin{aligned}
&E[w_k \mid w_k>0] \\
&=E[w_k]/Pr[w_k>0] \\
&=E[W\cdot(w_k/W) \mid W>0]Pr[W>0]/Pr[w_k>0] \\
&=\{Cor[W,w_k/W \mid W>0]Var^{1/2}[W \mid W>0]Var^{1/2}[w_k/W \mid W>0] \\
&+E[W \mid W>0]E[w_k/W \mid W]\}/Pr[w_k/W=0 \mid W>0]
\end{aligned}$$

where Cor[] denotes the correlation coefficient. In the above, the non-PQPF parameters, $Pr[w_k/W=0]$, $Cor[W,w_k/W \mid W>0]$ and $Var^{1/2}[w_k/W \mid W>0]$ are estimated from PQPF and climatology.

4. SPATIAL DOWN-SCALING OF PQPF

The HRAP grid-scale parameters, p_k and m_k, are estimated from the indicator correlation function, $Pr[w_k>0]$, and $E[w_k \mid w_k>0]$. First, to estimate p_k, we write:

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$\Pr[w_k=0]$
$=\Pr[R_k(u_1)=0,R_k(u_2)=0,\ldots,R_k(u_n)=0]$
$=\Pr[R_k(u_1)=0 \mid R_k(u_2)=0,\ldots,R_k(u_n)=0]$
$\cdot \Pr[R_k(u_2)=0 \mid R_k(u_3)=0,\ldots,R_k(u_n)=0]$
$\cdot$
$\cdot \Pr[R_k(u_n)=0]$
$\approx\{1-E[I_k(u_1) \mid I_k(u_2)=0,\ldots,I_k(u_n)=0]\}$
$\cdot \{1-E[I_k(u_2) \mid I_k(u_3)=0,\ldots,I_k(u_n)=0]\}$
$\cdot$
$\cdot \{1-E[I_k(u_n)]\}$

where the indicator random variable, $I_k(u_i)$, is defined such that its experimental value takes on 1 if $R_k(u_i)>0$ and 0 otherwise. In the above, $E[I_k(u_1) \mid I_k(u_2)=0,\ldots,I_k(u_n)=0]$, for example, may be estimated numerically via indicator kriging (Solow 1986) as follow:

$E[I_k(u_1) \mid I_k(u_2)=0,\ldots,I_k(u_n)=0]$
$=p_k+\Sigma\lambda_i(0-p_k)$
$=(1-\Sigma\lambda_i)p_k$

where λ_i's are the location- and indicator correlation-dependent weights to be solved for. With the above development, $\Pr[w_k=0]$ is written as a function of p_k, which can be easily solved for numerically via one-dimensional iterative root-finding.

Finally, given p_k, $\Pr[w_k>0]$ and $E[w_k \mid w_k>0]$, m_k may be obtained, under the assumption of local homogeneity of precipitation, from:

$E[w_k>0 \mid w_k>0]$
$=E[(1/A)\int_A R_k(u)du \mid (1/A)\int_A R_k(u)du>0]$
$=(1/A)\int E[R_k(u) \mid (1/A)\int_A R_k(u)du>0]du$
$=(1/A)\int E[R_k(u) \mid 1/A\int_A R_k(u)du>0,R_k(u)>0]$
$\cdot \Pr[R_k(u)>0 \mid (1/A)\int_A R_k(u)du>0]du$
$=m_k(1/A)\int_A \Pr[R_k>0 \mid (1/A)\int_A R(u,k)du>0]du$
$=m_k(1/A)\int_A \Pr[R_k>0]du/\Pr[w_k>0]$
$=m_k p_k/\Pr[w_k>0]$

Hence, we have:

$m_k=E[w_k \mid w_k>0]\Pr[w_k>0]/p_k$

5. EXAMPLE

Figs 1 and 2 show an example of 0-6 and 6-12 hr precipitation fields, respectively. They are based on $p_1=p_2=0.5$, $m_1=m_2=2.5$ (mm), $cv_1=cv_2=2$, indicator and conditional correlation scales of 80 and 48 km, respectively, and lag-1 Lagrangean autocorrelation of 0.6 under no advection. The major directions of anisotropy are 45° and 60°, and the major-to-minor anisotropy ratios are 2 and 2.5 for precipitation/no-precipitation and precipitation amount fields, respectively. The simulation domain is a 64x64 HRAP grid, representing an approximately 256x256 km^2 area. In both figures, the gray scale is linear, and the maximum precipitation is about an inch.

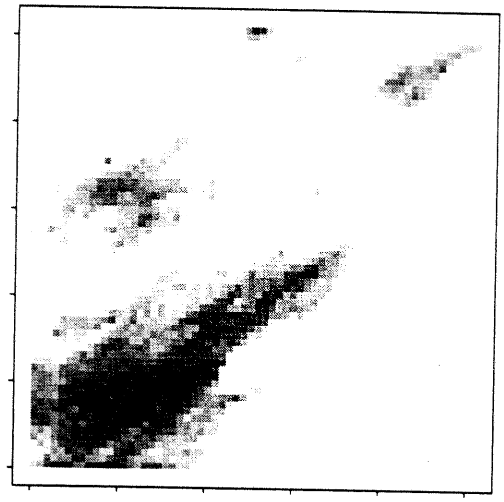

Figure 1. An example of simulated 0-6 hr field

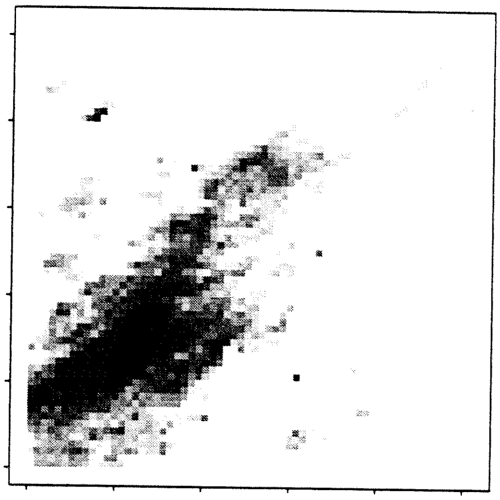

Figure 2. An example of simulated 6-12 hr field

6. REFERENCES

Deutsch, G. V., and A. G. Journel, 1992: GSLIB Geostatistical Software Library and User's Guide. Oxford University Press, 340pp.

Krzysztofowicz, R., and A. A. Sigrest, 1997: Local climate guidance for probabilstic quantitative precipitation forecasting. Mon. Wea. Rev., 125, 305-316.

___, T. A. Pomroy, 1997: Disaggregative invariance of daily precipitation. J. Appl. Meteor., 36(6), 721-734.

Seo, D.-J., 1997a: Real-time estimation of rainfall fields using rain gage data under fractional coverage conditions. accepted for publication in J. Hydrol.

——, 1997b: Real-time estimation of rainfall fields using radar rainfall and rain gage data. submitted to J. Hydrol.

Solow, A. R., 1986: Mapping by simple indicator kriging. Math. Geol., 18(3), 335-352.

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