Meetings

Meeting Report

Chapman Conference on Spatial Variability in Hydrologic Modeling*

The AGU Chapman Conference on Spatial Variability in Hydrologic Modeling was held July 21–23, 1981, at the Colorado State University Pingree Park Campus, located in the mountains some 88.5 km (55 miles) west of Fort Collins, Colorado. The conference was attended by experimentalists and theoreticians from a wide range of disciplines, including geology, hydrology, civil engineering, watersheds science, chemical engineering, geography, statistics, mathematics, meteorology, and soil science. The attendees included researchers at various levels of research experience, including a large contingent of graduate students and many senior scientists.

The conference goal was to review progress and discuss research approaches to the spatial variability of catchment surface and subsurface hydrology, and to identify areas for improved research. Mathematical models of water movement dynamics within a catchment consist of linked partial differential equations that describe free surface flow and saturated and saturated flow in porous media. Such models are utilized extensively in attempts to understand and predict the environmental consequences of human activities such as agricultural land management, waste disposal, urbanization, etc. We are concerned with the spatial structure of the parameters in such models, the precipitation input, and the geometric complexity of the system boundaries. The emphasis of this conference was on surface and subsurface hydrological processes and their interactions.

Until recently, there has been little development of spatial analyses in hydrology. In the last 4 years, groundwater hydrologists have pioneered the representation of aquifer parameters as the realization of two- or three-dimensional random processes, and the precipitation process has been described as a random field in space and time. The physics of water flow in the unsaturated zone in a heterogeneous, porous medium is particularly difficult because the water content tension and water content conductivity relationships must be considered as random functions. There has been little interaction between surface and subsurface hydrologists in establishing the appropriate time and space scales required to couple surface and subsurface models.

A substantial number of field data sets documenting spatial variability are now available. Although these data have been useful in describing the structure of the parameter and functional fields in the saturated and unsaturated zones, more effort is needed to use this information to devise a series of researchable questions about the distributed modeling of hydrologic systems. We hope that this conference will stimulate such activities. A major challenge to the research community is to incorporate the observed regularities in soil characteristics, stream channel networks, basin form, and geological formations, along with statistical information on variability within units, into an objective technique for spatial representation of watersheds.

Rafael Bras (MIT) set the tone for the conference by reviewing the recently conflicting conclusions of recent investigators on the importance of spatial variability of rainfall and the resulting precipitation excess on catchment response. He outlined a new distributed linear approach to estimating catchment response to rainfall excess, exploiting the basic order in stream systems as reflected in geomorphological indices. He found that—with a homogeneous random input—there is a spatio-temporal correlation increased, the output variance increased (i.e., the more noisy the rainfall, the better behaved was the output). A similar result for catchments with uniform rainfall but spatially varied hydraulic resistance was reported by Wu, Woolhiser, and Yevjevich (CSU and ARS-USDA).

Several investigators reported the results of field measurements of hydrologic properties of soils. Several Utah State investigators made direct measurements of the spatial variability of infiltration by using ring infiltrometers. R. J. Wagenet found that steady state infiltration rates were log normally distributed, and optimal infiltrometer spacing could be determined from regionally varied variable theory. Grab and Hawkins examined the relationship between infiltration rate and overland flow distance to the nearest channel. B. J. McGurk reported work by Gifford, Bowles, and Springer on spatial variation of infiltration from a plowed and seeded pasture and a native sedge site. M. Vaucin, G. Vachaud, and J. Imberson (Institut de Mecanique de Grenoble) found that for a 1-ha plot in Senegal the percent silt and clay has some correlation structure for $x<40$ m, but that other factors, such as sorptivity, steady state infiltration rate, volumetric water content, and hydraulic head, had no apparent spatial structure. Data presented by D. Fritton (Pennsylvania State University) illustrated the serious problems involved with the description of the soil water regime for plant growth models. P. Germann, K. Beven, and R. Chad (University of Virginia) presented a geometrical analysis of soil moisture data obtained from a three-dimensional grid at a forested site in Switzerland. Variograms demonstrated that correlations first decreased and then increased with horizontal distance, suggesting some large-scale spatial structure.

Watershed scale variability in soil moisture was described by M. E. Hawley, T. J. Jackson, R. H. McCuen, and G. A. Coleman (University of Maryland and ARS-USDA), and some simplified approaches to characterize spatial variability of soil water properties at this scale were identified. L. R. Ahuja (ARS-USDA). The effects of soil moisture variability on runoff were presented by B. J. McGurk (Utah State University), using the Stanford runoff model, and by H. A. Wilkening and R. Ragan (Univ. of Md.) using a numerical solution of the Richards equation. W. J. Wells and D. G. Green (ARS-USDA) reported the hydrologic characterization of some 4000 sets of soil water retention data from 1000 soils in 35 states. The Brooks and Corey parameters were estimated and transformed to normal distributions, and means and standard deviations were obtained for each soil textural class.

Spatial variability of soil properties often has a more significant effect on the transport of chemicals and sediments than on surface runoff response. A. Rogowski (ARS-USDA) used geostatistical methods to analyze the spatial structure of some unsaturated zone parameters of a field area and a digital image (inferred soil moisture data from an optical sensor). The hydrologic models were described by E. Goh and H. Hawkins examined the relationship between infiltration rate and overland flow response. He outlined a new distributed linear approach to estimating catchment response to rainfall excess, exploiting the basic order in stream systems as reflected in geomorphological indices. He found that—with a homogeneous random input—there is a spatio-temporal correlation increased, the output variance increased (i.e., the more noisy the rainfall, the better behaved was the output). A similar result for catchments with uniform rainfall but spatially varied hydraulic resistance was reported by Wu, Woolhiser, and Yevjevich (CSU and ARS-USDA).

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(STARMA) models to generate precipitation fields in time and space. G. Tabios and J. Salas (CSU) found that kriging and optimal interpolation techniques were superior to other methods commonly used to estimate annual precipitation at ungaged sites. S. Shih (University of Florida) presented a new method of determining the number of gages necessary to estimate mean watershed rainfall with a confidence level provided for the accuracy of the estimate. J. Harlin and J. Salisbury (University of Virginia) found that storms of different spatial patterns resulted in different representations and interpolation techniques. Using field data from the Quadrant Sand, a stratified unsaturated soil outcropping near Vancouver, Canada, as an example, he demonstrated the geostatistical techniques used to describe the spatial variability of such properties as porosity and hydraulic conductivity and the continuing need for data sets that characterize the spatial variability of porous media from different geological environments and on a variety of scales; said data to be used in evaluating theoretical models. He also pointed out the need to improve field techniques for obtaining representative statistical parameters, noting that horizontal continuities are especially difficult. Finally, he called for new methods of designing sample grids so as to reduce uncertainties in model prediction.

E. Bresler, D. Russo, and G. Dagan (Volcani Center and Tel Aviv University) measured saturated hydraulic conductivity, water entry pressure, saturated and residual water content, and sorptivity. Parameters characterizing the pore-size distribution were calculated. Each of the seven parameters was described as a realization of a stationary, two-dimensional random process characterized by density functions independent of spatial position and by autocorrelation functions between any two spatial points in the field. For their field study they found that autocorrelation functions approached zero at about 90 m, and the integral scale ranged from 25 to 75 m. T. Yeh and L. Gelhar (New Mexico Tech) analyzed the effects of spatial variability of parameters on unsaturated flow by solving stochastic state. Spatial distribution of partial differential equations. They found that the head variance derived for three-dimensional flow analyses is less than that of one-dimensional flow. Also, as the correlation length scale for saturated hydraulic conductivity and a water characteristic parameter increase, the one- and three-dimensional results converge, indicating that one-dimensional flow predominates. M. Cole and L. DeBacker (University of Louvain) described a statistical procedure to reduce the number of soil-moisture-measuring sites required to estimate watershed recharge.

In saturated porous media flow systems, hydraulic conductivity and porosity can be treated as a realization of a three-dimensional stochastic process. P. Kitanidis and E. Vomvoris (University of Iowa) used a first-order analysis to derive the statistical properties of the associated nonstationary random fields of piezometric head and discharge from solutions of the stochastic partial differential equations for steady flow in finite aquifers. They found that ratios of scales of parameter fluctuations to corresponding formation dimensions determine the variability of the piezometric head and discharge and also provide a criterion for the suitability of the first-order analysis. S. Mizell, L. Gelhar, and A. Gutjahr (EG&G and New Mexico Tech.) used spectral analyses techniques to investigate steady flow in infinite aquifers. They found that head fluctuations exhibit correlation over greater by a stochastic convective flow equation and are reduced as the dimensionality of the system increases. G. Dagan (Tel Aviv University) used a perturbation approximation for understanding flow in aquifers with varying conductivity. The results of tracer tests in a shallow, sloping unconfined aquifer were considered that the concept of dispersivity is general and not applicable.

On the final afternoon of the conference, discussion centered on the use of remote sensing techniques to obtain input data for distributed hydrologic models and in data management. Techniques to efficiently manipulate large amounts of data required for such models. J. Fellows (University of Maryland) presented a computer-based watershed development system that utilizes USGS-DIM digital terrain tapes and can develop a digital binary picture of a watershed and its stream network when the user inputs the location of the outfall cell. R. J. Gurney and T. J. Schumegger (NASA/Goddard Space Flight Center) discussed the remote sensing of soil moisture, which is important for initializing distributed hydrologic models. They presented examples of estimation of soil moisture variations, using airborne thermal infrared and passive microwave sensors. They also described the use of remotely sensed measurements of soil moisture in the optimal design of conventional soil moisture measurement networks. R. Rango and J. Fellows (University of Colorado, Boulder) considered the requirements of interfacing remote sensing and information management data, using the 1036-km² (400-mi²) Montgomery Co., Md., data as an example. Geographic information systems, utilizing threedimensional and rectangular, combined with distributed hydrologic models were described by W. Grayman and R. Males and J. Sarsenski, P. Koch, and W. Grayman (W. E. Montgomery Co.)...
Gates and Associates); and W. Strifler (CSU).
T. Croley III (NOAA) described a computer
algorithm for automatically ordering computa-
tions for a distributed surface runoff model
consisting of a network of spatially uniform
elements.
Panel discussions, ably chaired by D. Niels-
sen (University of California, Davis), H. Morel-
Seytoux (CSU), and A. Gutjahr (New
Mexico Tech), were held at the end of the
sessions each day to raise questions or point
out omissions in the day's discussion and to
relate the material to previous or subsequent
topics.

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