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Preface

The Fifth International Conference on Precipitation entitled "Space-Time Variability and Dynamics of Rainfall" was held in Elounda, Crete, Greece, June 14-16, 1995. The central theme of the conference was research issues related to the problem of linking stochastic and dynamic descriptions of rainfall for the purpose of modeling, estimation, and forecasting over a large range of scales. In particular, emphasis was placed on the following topics: (1) rainfall dynamics, (2) space-time variability and statistical characterization, (3) linkages between dynamic and stochastic descriptions, and (4) applications of physical and/or statistical theories in the development of rainfall estimation algorithms. Following the tradition of the previous four conferences (Caracas, Venezuela, 1986; Massachusetts Institute of Technology, 1988; Texas A&M University, 1991; University of Iowa, 1993), this meeting aimed at fostering interdisciplinary interaction among meteorologists, hydrologists, mathematicians, and statisticians having common interest in basic and applied rainfall research.

This issue of the *Journal of Geophysical Research* (Atmospheres) contains 31 papers presented at the conference. These papers are grouped under five broad topics, namely, dynamical modeling of rainfall, rainfall relationships to atmospheric conditions, statistical analysis of rainfall structures, stochastic and scaling theories of rainfall, and remote sensing rainfall estimation.

In the first group of papers, on dynamical modeling of rainfall, Georgakakos and Krajewski propose a kinematic-microphysical space-time rainfall model which is computationally efficient and can be used for high-resolution (less than 1 × 1 km) rainfall simulation. With randomized input and boundary fields, the model is used in a Monte-Carlo mode to elucidate links between statistical theories of rainfall and kinematic-microphysical theories of rainfall production mechanisms. Nakakita, Ikebuchi, Nakamura, Kanmuri, Okuda, Yamaji, and Takasao present a physically based short-term rainfall prediction model which tries to bridge the gap among scales of radar information, upper air observations, and numerical weather prediction and which promises improved prediction over lead times of three to four hours. Liu, Avissar, and Giorgi evaluate the ability of the regional model RegCM2 to predict anomalous precipitation. By simulation of the East-Asian flood of May-July 1991 they conclude that a major deficiency of the model is its overestimation of rainfall by up to 30% and a bias in the simulated position of the rain belt. Lagouvardos, Kotroni, Dobricic, Nickovic, and Kallos employ two well-known models: the Colorado State University regional atmospheric modeling system (CSU RAMS) and the operational (ETA/NMC) model and by intercomparison explore the capabilities and limitations of each model in simulating an extreme event over Greece. Petroliagis, Buizza, Lanzinger, and Palmer evaluate the skill of the European Centre for Medium-Range Weather Forecasts (ECMWF) ensemble prediction system (EPS) to provide confidence measures of high-resolution rainfall forecasts and conclude that probabilistic rainfall predictions are less skillful than forecasts of other atmospheric variables.

In the second group of papers, on rainfall relationships to atmospheric conditions, Eltahir and Pal study the relationship between surface conditions (described by the surface wet-bulb temperature) and subsequent convective storms (described by the probability of occurrence of storms and the average storm rainfall). They use these relationships to examine the potential impact of land cover changes on rainfall patterns in the Amazon region and the Columbia river basin. Rauber, Laird, and Ochs III examine the magnitude and distribution of rainfall within trade wind clouds east of the Hawaiian Islands and conclude that the efficiency of these clouds in returning water evaporated from the ocean surface back to the ocean through rainfall is no more than 20 to 30 percent. Sioutas and Flocas examine the possibility of using environmental wind data (and especially vertical wind shear) for assessing predictability of the propagation, storm structure and evolution of thunderstorms in northern Greece. By comparison of the propagation of multicell and single cell thunderstorm echoes relative to the cell motion, mechanisms of new cell growth are also suggested for multicell thunderstorms. Mamassis and Koutsoyiannis study the influence of the prevailing weather and atmospheric circulation types to improve rainfall prediction in terms of the probability of occurrence and distribution of intense rainfall events. They suggest that the concept of weather types can feasibly contribute to the estimation of the probability of occurrence of an intense rainfall event but not to the quantitative short-time prediction of rainfall intensities.

In the third group of papers, on statistical analysis of rainfall structures, Bacchi, Ranzi, and Borga examine the spatial organization of rain cells in storms and propose methods for parameter estimation of phenomenological cluster-type models of rainfall. Skaugen, Creutin, and Gottschalk study relationships

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between the fractional coverage of a catchment where it rains above a given threshold and find that, for a range of rainfall intensities, the ratio between two fractional areas of consecutive thresholds is independent of the actual value of the rain intensity and the size of the considered catchment. They use these relationships for the purpose of estimating extreme mean areal rainfall. Gershunov and Michaelsen study climatic-scale space-time variability of tropical precipitation, including seasonality, intraseasonal variability and El Nino-Southern Oscillation anomalies. They find that all coherent modes, despite having much of their energy concentrated around rather different frequencies, show signs of interaction. Cahalan, Wharton, and Wu perform an empirical orthogonal function (EOF) analysis on monthly mean precipitation and temperature variability over the United States and document departures of the observed EOF eigenvectors from those of homogeneous models hinting to the presence of inhomogeneities which need further study to be associated to physical attributes.

In the fourth group of papers, on stochastic and scaling theories of rainfall, Over and Gupta propose a space-time framework of rain by extending discrete independent and identically distributed multiplicative cascade spatial models to stochastic processes indexed by time and evolving in response to an externally specified non-stationary large-scale forcing. The anisotropy between space and time dimensions in the model is shown to lead to the prediction of the breakdown after a short time of Taylor's hypothesis of turbulence, as empirically observed. Marsan, Schertzer, and Lovejoy explore a space-time rain model based on scaling dynamics, that is, the model phenomenology corresponds to a cascade of structures with lifetimes depending only on the scale of the structures. They also study issues related to the scaling anisotropy between space and time and a fundamental asymmetry between past and future (causality). Perica and Foufoula-Georgiou propose a scaling model for spatial rainfall downscaling (that is, from large to small scale variability) of midlatitude mesoscale convective systems. It is based on evidence of statistical simple scaling in standardized rainfall fluctuations and demonstration that the scaling parameters can be reasonably well predicted from the convective available potential energy (CAPE) in the prestorm environment. Cârsteanu and Foufoula-Georgiou examine the suitability of independent-weight multiplicative cascade models for temporal rainfall. They conclude that generators with negatively correlated weights provide better models for temporal rainfall than independent cascades and are consistent with an antisymmetry which is present in atmospheric turbulent eddies. Veneziano, Bras, and Niemann examine high-resolution (5s) rainfall data to revisit the issue of self-similarity and multiplicative versus additive model structure for temporal rainfall. They argue against multifractal representations and propose a lognormal model with a segmented log spectrum. Kumar uses time-frequency-scale analysis to reveal essential dynamics of temporal rainfall which are identified as coherent structures. He shows the existence of distinct scales of variation identifiable with rain cell and synoptic-scale activity and also argues against the scale invariance hypothesis for temporal rainfall. Harris, Menabde, Seed, and Austin study the relation of multifractal characteristics of rainfall to physical properties of the landscape (orography) by analyzing 15s data over a transect from the base to the divide of a mountain. They show a systematic trend in the scaling exponents, indicating a decrease in intermittency, the frequency of extreme values, and smoothness of the time series with increasing altitude along the transect. Onof, Northrop, Wheater, and Isham analyze British rainfall data for Taylor's hypothesis and multiscaling and examine the ability of Poisson-based cluster models to reproduce self-similarity properties of rainfall. Tessier, Lovejoy, Hubert, Schertzer, and Pecknold study rainfall and runoff time series under the framework of universal multifractals and quantify the scaling regimes and types of scaling of these variables. They then try to relate the low-frequency rainfall series to the corresponding river flow series via a simple scaling transfer function. Koutsoyiannis and Pachakis use nonlinear analysis tools to analyze historic 15min rainfall data and synthetic data generated by a stochastic self-similar model. They find no substantial difference in the correlation dimensions of the synthetic and historic records and no evidence of low-dimensional determinism, suggesting that in many cases, simple stochastic models might be adequate for describing the nonlinear dynamical properties of rainfall.

In the fifth group of papers, on remote sensing rainfall estimation, Soman, Valdes, and North analyze radar echoes from Darwin, Australia, to determine the time and length scales of the precipitation fields and evaluate sampling errors based on the obtained space-time spectra. They find significant sampling errors of as high as 65% for 24-hr sampling intervals. Gorgucci, Scarchilli, and Chandrasekar present a procedure to estimate absolute and differential attenuation at C-band frequencies from dual polarization radar measurements and develop an algorithm to correct for this attenuation. They show that attenuation correction improves the radar rainfall estimates based on Z-R algorithms but not always the estimates based on dual polarization algorithms. Fokianos, Kedem, and Short propose a generalized logistic regression model for statistical analysis of multicategorical time series and explore its applicability to rainfall estimation from Tropical Ocean and Global Atmosphere/Coupled Ocean-Atmosphere Response Experiment (TOGA/COARE) data. Lovejoy, Duncan, and Schertzer reexamine the classical radar observer's problem (of interpreting the fluctuating radar echo from precipitation) in light of multifractal theories and suggest the need for new theories relating radar measurements to rain. They also argue that radar speckle is a general consequence of multifractal liquid water/drop correlations. Krajewski, Anagnostou, and Ciach present a simulation study that demonstrates that both the physics of the radar measurement process and the processing of radar data can have significant effects on inferred rainfall statistics (such as mean, variance, covariance, and certain scaling parameters). They caution rainfall researchers to consider this factor while developing new rainfall theories based on properties inferred from radar measurements. Li, Bras, and Veneziano show that high brightness temperatures (typically associated with rainfall using physical and statistical models) can be caused by nonprecipitating clouds and by wind. They develop a model to relate high brightness temperature to the fractional coverage of rain within a field of view and an empirical model to relate fractional coverage to rain rate. They then apply their model to the estimation of rain rates in TOGA/COARE and Darwin storms. Tsonis, Triantafyllou, and Georgakakos investigate the ability of satellite visible and infrared data to produce reliable daily rainfall amount estimates to be used in hydrologic modeling for runoff prediction in large basins. Their results show that differences between rain gage and satellite rainfall input, generate differences in flow forecasts and upper soil water model-estimates which are a function of the antecedent soil-water conditions. In a companion paper, Guetter, Georgakakos, and Tsonis quantify these differences and conclude that improvement of flow simulation by use of satellite rainfall depends on the basin scale (larger improvement for larger basins). These conclusions are based on analysis of three basins (2000 to 14,000 km^2) in the upper Des Moines River basin in the midwestern United States.

Overall, it can be said with certainty that considerable progress has been made over the past several years on rainfall modeling, estimation, and prediction. At the same time however, rainfall still remains one of the hardest variables to accurately predict in atmospheric models and one of the hardest variables to quantitatively describe its complex space-time dynamics and their connection to physical properties of the storm environment. New rainfall measurement efforts (e.g., the next generation radar, NEXRAD) promise the availability of data which will be useful in further testing existing hypotheses and models and also connect statistical and physical rainfall parameterizations. A main effort in the next few years has to be made to understand the limits of rainfall predictability as a function of space-time scale and also how this predictability can be enhanced by combining physical descriptions at larger scales with statistical descriptions at smaller scales. Scaling theories of rainfall offer great promise on this problem, as they permit efficient parameterizations over a large range of scales. Another important problem to be addressed in the future is the effect of rainfall space-time dynamics and scale at which these are accurately predicted, on the prediction of other hydrologic variables via land-atmosphere coupled modeling. Efforts should also continue on improving radar and satellite rainfall estimation based on new technologies and also on improved understanding of the physical and statistical characteristics of the rainfall phenomenon.

The Fifth International Conference on Precipitation was sponsored by the American Geophysical Union, American Meteorological Society, and European Geophysical Society. It had the financial support of the National Science Foundation, National Aeronautics and Space Administration, Commission on European Communities, and the Greek National Hail Suppression Program. The conference main social event was hosted by the Municipality of Aghios Nicolaos, Crete. The conference was attended by 120 scientists and had a large European participation (56 scientists from Europe, 55 from the United States and Canada, and the rest from other countries). The organizers (Efi Foufoula-Georgiou, University of Minnesota, Minneapolis, and Anastasios Tsonis, University of Wisconsin, Milwaukee) want to extend their thanks to all the members of the organizing committee (Roni Avissar, Ian Cluckie, Dominique Creutin, Mike Fritsch, Vijay Gupta, Demetris Koutsoyiannis, Shaun Lovejoy, Roger Pielke, Jim Smith, Ezio Todini), ex-officio members (Konstantine Georgakakos and Witek Krajewski), and the members of the local organizing committee (Michalis Sioutas and Themistocle Xanthopoulos). Special thanks go to Demetris Koutsoyiannis who offered invaluable help with the local arrangements. Also, special thanks go to all the reviewers of the submitted papers for their unselfish and prompt response in providing constructive and thoughtful reviews. Pat Swanson offered expert and dedicated editorial help, from the conception of this conference to the final production of this volume. Alin Cârsteanu and Venugopal Vuruputur helped with the camera-ready production of two papers that otherwise would not have made the special issue deadline. We extend our deepest appreciation and thanks to all the agencies that made this conference and reprint volume possible and to all the people who helped make it a great success. The Sixth International Conference on Precipitation is organized by Roni Avissar at Rutgers and Jim Smith at Princeton University and will be held in Hawaii in the spring of 1998.

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Guest Editors