H41A CC: 406 Thurs 0830h
Precipitation Measurement, Simulation, and Analysis I *(joint with A)*
Presiding: **A Kawamura**, Kyushu Univ; **E Foufoula-Georgiou**, Univ of Minnesota

H41A-1 0830h INVITED
The unified scaling model of atmospheric dynamics and systematic analysis of satellite and radar data

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The unified scaling model of the atmosphere links the large and small scale dynamics by a single scaling but anisotropic regime, rather than the distinct isotropic two and three dimensional turbulent regimes posited in the standard model. We argue that study of mesoscale clouds and precipitation is a particularly stringent test for the standard model and we present (perhaps the first) systematic analysis of the scaling of energy spectra of satellite radiances over five wavelength channels and spanning the range of scales 160m to 4000km (the entire mesoscale). We also study radar reflectivities of rain over the range 150m to 100km. The most intensively studied set involved 15 consecutive scenes of AVHRR data (1.1km resolution, 512X512 pixels) taken over the same location at same local time in February 1986. This data was chosen because it was expected to provide a very sensitive indicator of the mesoscale break in the scaling predicted by the standard model of atmospheric dynamics (the "mesoscale gap"). Over the entire range, with surprisingly little scene to scene variation, the (isotropic) energy spectrum (E(k)) was found to follow the scaling form $E(k) \approx k^{-\beta}$ where k is a wavenumber, and β is the spectral exponent. This type of behaviour is exactly as predicted by the unified scaling model of the atmosphere as the outcome of anisotropic nonlinear cascade dynamics. It is hard to see how these results can be reconciled with the standard model.

Finally, cascade theories based on nonlinear scaling dynamics predict that the scaling properties should be "universal"; when the same basic dynamical mechanism is repeated from one scale to another over a large range with many nonlinear interactions, the result is independent of many of the details of the dynamics, it depends on only three basic parameters. The double trace moment technique was used to estimated these parameters in rain and cloud radiances.

H41A-2 0855h
Lie Cascades of Rain: Multifractal Vectorial Analysis and Simulations

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Usual scalar multiplicative cascade processes are in fact restricted to positive scalar fields, since an exponential of a real number is positive. This is an unnecessary restriction for multifractal fields, since the rain fluxes from larger to smaller scales are not always positive.

This restriction is overcome as soon as we consider multiplicative processes on the complex plane. More generally vectorial and tensorial extensions of multiplicative processes are discussed, as well as the even more general Lie algebra of the multiplicative processes. They provide us with a theoretical framework for dealing with nonlinearly coupled cascade processes acting over a wide range of scales, e.g. between the dynamics and the rain field.

We present simulations of complex-valued multifractal fields, and test on them vectorial extensions of multifractal analysis techniques (Probability Distribution Multiple Scaling, Double Trace Moment...) and discuss their application to rain measurements and forecast.

H41A-3 0915h INVITED
Fractal and Multifractal Analysis of Time Rainfall Series

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(Sponsor : E. Foufoula-Georgiou)

More and more evidence of the extreme variability and intermittency of rainfall processes have been given, especially save to modern rainfall recording devices (the time step of which may be the second) and to radar and satellite imagery.

At first, fractal techniques seemed to be relevant in order to describe rainfall time series from a geometrical point of view. Unfortunately they did not yield as expected a unique fractal dimension but an infinite hierarchy of fractal dimensions according to some kind of rainfall intensity threshold. This problem has been overcome using (universal) multifractal fields, as defined by Schertzer and Lovejoy for multiplicative processes. These models are characterized by only three parameters, H relative to fluxes conservation, α (Levy index) measuring departure from monofractality and C_1 rating deviation from homogeneity.

Starting from the basic equations of universal multifractals, some calculus enable us to derive an expression of the precipitation depth within a given duration which has a given probability to be exceeded (which is nothing but the classical Intensity Duration Frequency curves). It is noteworthy that, as far as the α parameter remains bounded by 0 an 1 (which seems to be the case for rainfall intensity), this precipitation depth tends towards a finite limit as the probality of exceedance tends towards zero, so defining rigorously a maximum possible precipitation, which can be estimated, like the H, α and C_1 parameters, from empirical data.

An application from a 45 years long African daily rainfall time series is proposed.

H41A-4 0940h
On the Concept of Similar Storms and Their Parametrization via Scaling

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Empirical evidence suggests that statistical properties of storm rainfall within a homogeneous season have a well structured dependence on storm duration. For example, the mean and standard deviation of total storm depth increase with duration each according to a power law with the same exponent; the lag-one correlation coefficient of hourly rainfall depths increases with duration; and the decay rate of the autocorrelation function of hourly rainfall depths decreases with duration. Motivated by the first observation, a simple scaling model for rainfall intensity within a storm was hypothesized and was shown both analytically and empirically that such a model can explain reasonably well the observed statistical structure in the interior of storms providing thus an efficient parametrization of storms of varying durations and total depths. This simple scaling model is also consistent with, and provides a theoretical basis for, the concept of mass curves (normalized cumulative storm depth vs. normalized cumulative time since the beginning of a storm) which are extensively used in hydrologic design.

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H41A-5 1020h
Modeling Spatial Rainfall via Bivariate Multifractal Measures

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A new representation for spatial rainfall, based on fractal interpolation functions and multifractal measures, is introduced. The proposed model may be applied to rainfall snap-shots and is entirely deterministic. It is shown via simulations that it preserves the inherent intermittency and spatial variability features present in rainfall fields. Despite being deterministic, the model results in three-dimensional multifractal rainfall fields that may contain very extreme (latent) events, i. e. negative values on their multifractal spectrum. A comparison between the proposed model and those based on random cascades is given.

Plausible representations of the space-time evolution of rainfall are discussed.

H41A-6 1040h
Radial Spectrum Estimation of Heavy Storm over the South Korea

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Rainfall is a phenomenon that shows a high variability both in space and time, we are specially interested in the description of spatial distribution of heavy storm over the south Korea during the period of flood season. In order to search the characteristics of the regional component, a number of storms over the Han river and the Gum river basin in the south Korea are analyzed. The goal of this analysis is to investigate whether or not there exists a persistent pattern in total storm depths over a given area. The multi-quadratic equation(MQ) and the generalized covariance(GC) method were used to construct random surface of total storm depth. For the surface, the double Fourier analysis of the depths was performed and storm residuals was obtained. It is assumed that the residuals are a sample function of a homogeneous random field. This field can be characterized by an isotropic one dimensional autocorrelation function or its corresponding spectral density function(SDF). For each basin, the SDF based on MQ and GC was estimated respectively and the results were compared.

H41A-7 1100h INVITED
Real-Time Prediction of Small-Scale Spatio-Temporal Rainfall Using a Raingage Network System

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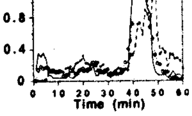
There are distinct needs to develop real-time prediction methods and models of spatio-temporal rainfall structures in urban areas for the on-line decision making process to optimize the operation of urban hydrological systems. Thus, the rainfall scale that is of main interest is small and a prediction time scale typically less than one hour and the space scale of a few square kilometers and smaller. The rainfall variation on this scale generally corresponds to the behavior of individual rain cells.

In this paper, a model methodology based on a two-dimensional stochastic convection-diffusion equation is developed to predict in real-time the spatial rainfall distribution on the aforementioned time and space scales using the observation in a raingage network system at ground level. The prediction is done by expanding the rainfall intensity field into Fourier series. The extended Kalman filtering procedure is effectively used to identify and continuously update parameters of the model and the Fourier coefficients.

Short-term (1-minute interval) high-intensive rainstorms have been observed during several years in a dense twelve-gage network system for rainfall observation in the city of Lund, Sweden. The aforementioned methodology is applied to ten rainfall events chosen from these observations for real-time prediction of the rainfall and for the identification of the unknown parameters of the model. The figure shows a part of the results of the 1 and 5-minute ahead prediction for one gage. Parameter alternatives and factors which affect the forecast accuracy are discussed. The model is especially suitable for raingage network systems. Since a Fourier domain shape method is used for the rainfall field and coupled Gaussian noise, the model domain needs not to be discretized. This has special advantages for irregularly spaced gaging systems.



H41A-8 1125h
A Dynamic Model of the Space-Time Distribution of Precipitation in Remote Mountainous Areas

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Precipitation in remote mountainous areas dominates the water balance of many water-short areas of the globe, such as western North America. The inaccessibility of such environments prevents adequate measurement of the spatial distribution of precipitation, and hence direct estimation of the surface water balance from observations of precipitation and runoff. Resolution constraints in numerical weather prediction models can likewise result in large biases in prediction of the water balance for grid cells which include diverse topography. Modeling of the advection of moisture over topographic barriers at a spatial scale sufficient to resolve the dominant topographic features offers one method of better predicting the space-time distribution of precipitation in such areas. We describe a model that simulates Lagrangian transport of moist static energy and total water through a three dimensional finite element grid, where precipitation is the only scavenging agent of both variables. The model is applied to the Olympic Mountains, Washington, and is verified using eight years (1967-74) of high elevation annual catchment precipitation estimated via water balance, seasonal precipitation at snow courses, and seasonal and daily low elevation precipitation gage data. Preliminary results for application of an extended version of the model, which includes a surface energy and hydrology representation, to the Sierra Nevada Mountains in the western U.S. are presented. The Sierra Nevada application is validated using an extensive network of precipitation gages and snow courses for the American River basin, California.

H41A-9 1145h
Wavelet Transforms: A New Tool for Hydrologic Modeling?

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The Fourier transform has been a popular and useful tool for the analysis and modeling of hydrologic signals. However, it suffers from some limitations, such as it cannot handle signals with transient components. It also does not convey any information pertaining to translation of the signal in time. The wavelet transforms, recently introduced, overcome these problems and provide representations of the signal that are localized