each river basin, and to assess the validity of the hydrologic landscape concept. The long term climate history is then used to drive a transient simulation that will be used to study the effect of seasonal, inter-annual, and decadal climate patterns and land use on the persistence of wet and dry cycles in soil moisture, on recharge, and on the regional water budget as a whole.

H31C-05 0830h POSTER

Regional Groundwater Modeling for Source-Area Delineation and Recharge Estimation From Long Term Climate Forcing

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This research is developing a 3D groundwater model of the Spring creek and Spruce creek drainage basins in central Pennsylvania. The purpose of the model is to evaluate the source-area for drinking water supplies, rates of areal and focused recharge and the long-term effect of seasonal, annual and decadal climate variations on recharge and groundwater levels. A solid body model is developed to represent the hydrostratigraphy from borehole data and geologic cross-sections. The hydrostratigraphic model allows parameterization of the 3D model using GIS (Geographical Information System) tools and the GMS groundwater modeling system. Other necessary software includes the HUF package, Modflow and Modpath. At this time we have developed a GIS data-model for climatic inputs and parameters including topography, geology, precipitation, and evapotranspiration. The data-model is fully compatible with the physical model. Preliminary results for a simple 2 layer model simulation shows the importance of terrain and hydrostratigraphy on the simulated flow field. At present the model is being used to determine the distribution of residence time or travel time from all points within the basin to the outlet using Modpath. The poster will show estimated rates of recharge over the basin. The model is used to predict the subsurface groundwater divide between the Spring creek and Spruce creek basins. In this case we show that the topographic divide and groundwater divide are not coincident.

H31C-06 0830h POSTER

Evapotranspiration from Wetland Pond Complexes in the Western Boreal Forest, Alberta, Canada

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Wetlands on the Canadian Western Boreal Plain account for as much as 50 % of the landscape and provide one of the most important waterfowl habitats in North America as well as representing a significant regional water resource and carbon pool. In this sub-humid region potential evapotranspiration (PET) exceeds precipitation in most years and consequently these wetland complexes are very vulnerable to any climate change that may alter patterns of precipitation and evapotranspiration. The permanence of these wetland and pond systems depends on the underlying glacial deposits, topography and evapotranspiration. Flow within these wetland pond catchments is from the pond to the hillslope for most of the time and small changes in precipitation can result in a dramatic change in runoff. Increased climatic variability (natural or anthropogenic) will likely influence the duration of drought cycles. However, whether or not, or for how long these ponds may dry completely remains unknown. Thus, it is essential to understand the ecological and physiographic factors within these complexes that control evapotranspiration, and how these are influenced by large scale climate and climate cycles. This paper investigates not only open water evaporation from the ponds, but also the role of ET from the surrounding riparian peatlands, and illustrates how the evaporative regimes from these units and their linkages with the ponds are significant to the permanence of these water bodies.

H31C-07 0830h POSTER

Assessing the Impacts of Land Use Change and Increased Precipitation on Streamflow

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Increased precipitation, one aspect of climate change, has been documented in many parts of the United States and may lead to increased streamflow and flood frequency. Urbanization can also increase streamflow by elevating runoff levels through the addition of impervious surfaces. Increased precipitation and urbanization have occurred simultaneously in many areas, necessitating the quantification and separation of their impacts in order to advance our understanding of changing flood frequencies and magnitudes. This study is an examination of the relative impacts of combined changes in precipitation events and land use on flooding in small watersheds. Watersheds selected for analysis are distributed throughout the climate regions of the United States. Each has over 50 years of precipitation and streamflow data, a distinct land use, and an area less than 100 km2. Watershed selection is based on these criteria, with streamflow and precipitation trend analysis to be conducted after site selection is complete. Quantitative examination of upstream land use change in conjunction with precipitation change will constrain the factors influencing streamflow and flooding. By analyzing spatial and temporal trends in precipitation and streamflow for climatically-varied watersheds, this study will improve our understanding of process interactions in a complex environmental system responding to climate change.

H31D CC: 220 C-E Wednesday 0830h

Percolation and Related Processes in Porous Media Posters *(joint with NG)*

Presiding: **R P Ewing,** Iowa State University**; P R King,** Imperial College London

H31D-01 0830h INVITED POSTER

Hydraulic Properties of Unsaturated Porous Media From Percolation Theory

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Percolation theory can be used to calculate transport properties in disordered media, such as solute diffusion and the hydraulic conductivity. Experiments have shown that diffusion of solutes in porous media vanishes linearly as threshold moisture content is approached. An empirical relationship gives the threshold moisture content as approximately the square root of the surface area to volume ratio of the medium. The first relationship demonstrates the relevance of percolation theory in its continuum application (non-zero transport in a given phase requires phase continuity), while the second can be shown to be based on the validity of a fractal description of the medium. Percolation-type scaling behavior of the unsaturated hydraulic conductivity is not observed; in fact critical path analysis from percolation theory using the threshold moisture content for the critical moisture content for percolation gives the hydraulic conductivity in agreement with experiment. However, cross-over from the validity of critical path analysis to the percolation scaling regime is accompanied by a rapid change in the slope of the conductivity, leading to rapid increases in experimental equilibration times, failure to observe equilibrium pressure-saturation relations, and excess water in the medium for a given tension. These effects confound interpretation of experiments, but unification within a percolation perspective allows quantitative predictions of both the equilibrium and non-equilibrium behavior.

H31D-02 0830h INVITED POSTER

Network Models of Pore Structure and Percolation Theory Concepts for Modelling Capillary Pressure Curves and Relative Permeability Characteristics.

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Network models of pore structure using percolation theory concepts were developed at the University of Waterloo by Chatzis and Dullien since 1976. At present, the modeling of pore structure, capillary and transport phenomena in porous media using network models that incorporate percolation theory concepts is commonly performed by many researchers word-wide. A key feature in the use of network models is assign pore structure data for pore throats to the bonds of a lattice and pore structure data for the pore bodies to the sites of the lattice. The manner in which the pore structure data are assigned to the bonds and to the sites of a lattice is very critical in determining the pore space accessibility to the non-wetting phase, the capillary pressure characteristics and the two phase flow properties of network models, which in turn are utilized for the prediction of capillary pressure curves and relative permeability curves. There is a plethora of publications where bond percolation type of analysis is being performed with no special attention given on pore size and the corresponding pore volume assigned to a particular pore size in the network model. An attempt is made to clarify this contentious issue in the literature. Another equally important issue is that of percolation threshold probability and how the spatial variation of distributing pore structure information affects the pore space accessibility and two-phase flow characteristics of such network models. Examples of results obtained in our research group over the past 20 years along with that of others in literature will be also presented and discussed.

H31D-03 0830h POSTER

Diffusion Iso-Surfaces and Correlation Lengths in Low-Connectivity Structured Rock

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Diffusive exchange between flowing fractures and the tuff matrix is hypothesized to be a major retardant in the migration of radionuclides from the proposed nuclear waste repository at Yucca Mountain, NV. Studies and simulations to date have assumed that the tuff matrix can be treated as a homogeneous, low-diffusivity medium. However, a recent study by Hu and Ewing showed that the tuff porespace is only slightly above the percolation threshold, meaning that diffusion scales with distance up to the percolation correlation length X. Knowing this length could substantially improve predictions of diffusive retardation. This length X in a structured medium is presumably $X = X_0\ (\Theta - \Theta_c)^v$, where X_0 is the correlation length of the medium's structure, Θ is volume wetness, the subscript c denotes the critical volume for percolation, and v is the length exponent from percolation theory. Using random walk simulations on low-connectivity structured lattices, we evaluate our hypothesis that the correlation length can be given as the length at which diffusion iso-surfaces change from fractal to non-fractal.

H31E CC: 520 A Wednesday 0830h

Advances in Understanding the Global Water Cycle I

Presiding: **J Entin,** NASA Headquarters**; R Avissar,** Duke University**; R G Lawford,** International GEWEX Project Office International GEWEX Project Office

H31E-01 0835h

Emerging Opportunities in Synergistic Water Cycle Research

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The Science Steering Group (SSG) of the US Global Climate Research Program (US GCRP) Global Water

Cycle (GWC) reviewed the current state of the science and identified gaps of knowledge essential to advance the field. Analyzing the research opportunities proposed by the various agencies in collaboration with the scientific community, the SSG points out that coordination between the planned activities would provide significant synergistic benefits. A report of the SSG discussions and conclusions will be presented.

H31E-02 0850h

NASA's Earth Science Enterprise's Water and Energy Cycle Focus Area

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Understanding the Water and Energy cycles is critical towards improving our understanding of climate change, as well as the consequences of climate change. In addition, using results from water and energy cycle research can help improve water resource management, agricultural efficiency, disaster management, and public health. To address this, NASA's Earth Science Enterprise (ESE) has an end-to-end Water and Energy Cycle Focus Area, which along with the ESE's other five focus areas will help NASA answer key Earth Science questions. In an effort to build upon the pre-existing discipline programs, which focus on precipitation, radiation sciences, and terrestrial hydrology, NASA has begun planning efforts to create an implementation plan for integrative research to improve our understanding of the water and energy cycles. The basics of this planning process and the core aspects of the implementation plan will be discussed. Roadmaps will also be used to show the future direction for the entire focus area. Included in the discussion, will be aspects of the end-to-end nature of the Focus Area that encompass current and potential actives to extend research results to operational agencies to enable improved performance of policy and management decision support systems.

H31E-03 0905h

The Global Water System Project: Integrative Studies of the Water Cycle (invited)

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The water cycle figures prominently in the study of global change. In addition to greenhouse warming and concerns about an accelerated hydrologic cycle, several other anthropogenic factors interact with the water system to produce potentially global-scale effects. Prominent among these are widespread land cover change, urbanization, reservoir construction, irrigated agriculture, destruction of aquatic habitat, and pollution. A rich history of research at the local scale demonstrates the clear impact of such factors on the environment. Evidence now shows that humans are rapidly embedding themselves in the basic character of the water cycle over much broader domains. The collective significance of such a transformation of a basic element of the Earth system remains fundamentally unknown. This presentation summarizes a new project launched as part of the Earth System Science Partnership (ESSP) of the Global Environmental Change Programs (Diversitas, IGBP, IHDP, WCRP) that will study these water cycle changes. The aim of the GWSP is to catalyze our understanding of the dynamics of water in the Earth system, the unique role that humans play in the hydrologic cycle and reciprocal interactions between the biogeophysical and human components of the coupled system. A major emphasis will be on interactions, feedbacks, and thresholds, necessitating a balanced consideration of all factors at play– physical, chemical, biological, and societal. The GWSP is the product of contributions made by a broad cross-section of the water science and assessment community, with more than 150 contributors to a series of planning meetings, science scoping documents, and a recent Open Science Conference (October 2003; Portsmouth, NH). This paper reviews the scientific rationale for the initiative, presents the Project's key science questions, and describes the emerging agenda for study. Contributions from the North American science community will be reviewed.

H31E-04 0920h INVITED

Towards a Global Water Cycle Theme within the Integrated Global Observing Strategy (IGOS) Framework

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Over the past three years a number of scientists, international programs and national agencies have been working towards the establishment of a water cycle theme within the IGOS-Partnership. The current theme definition provides a framework for guiding decisions regarding priorities and strategies for the enhancement of water cycle observations in support of 1) monitoring climate variability and change, 2) effective macroscale water management and sustainable development of the world's water resources, 3) local societal applications for resource development and environmental management, 4) initialization of prediction models, and 5) priority water cycle science questions. Based on a review of the needs, adequacy, and priorities for water cycle observations outlined in a theme report, the theme was adopted by IGOS-P in November 2003. After briefly tracing the contributions of observations in the development of civilization, this presentation will provide an overview of the assessments of water cycle observations from the theme report and discusses recommended priorities for the enhancement and integration of water-related observational systems. The steps being taken to implement this theme will also be described. The talk concludes with a possible vision for new approaches to water resources management through broad acceptance of the principles of this theme and the development of the requisite water cycle science.

H31E-05 0935h

Precipitation variability and predictability in the GFDL General Circulation Model

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The AM2P11 version of the GFDL FMS GCM is intergrated for 22 years (1979-2000) in an AMIP-type setup with 16 ensembles. The variability of annual and seasonal precipitation is studied. We have speculated that the precipitation variability can be related to several components of the climate system, including the Sea Surface Temperature(SST), the land surface and the atmosphere itself, following the work by Koster et al. (1995). A series of experiments were carried out where the variations of these components are enabled or disabled. The changes in precipitation variability from one experiment to another are considered to be directly related to the changes in the boundary conditions. We have identified regions that are sensitive to SST variations and regions where land boudary condition also plays an important role, hence there is potential predictability of precipitation in the GFDL GCM given the SST and soil moisture information. This potential predictability study provides us guidence on where and when the land surface will help to improve the seasonal-to-interannual predictions. For regions where land surface is important, a good soil moisture initialization scheme is expected to be able to improve the seasonal prediction, in conjunction with an accurate SST forecast.

H31E-06 0950h

Evidence for Intensification of the Global Hydrologic Cycle: Review and Synthesis

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One of the more important questions in hydrology is whether future climate warming will result in an intensification of the hydrologic cycle and, if so, what the nature of that intensification would be. An intensification of the hydrologic cycle involves net global increases in evaporation, evapotranspiration, and precipitation. Such an intensification may lead to changes in water-resource availability and an increase in the frequency and intensity of major storms, floods, and droughts. This paper briefly reviews the current state of science regarding historical trends in hydrologic variables, including precipitation, runoff, tropospheric water vapor, soil moisture, lower stratospheric water vapor, glacier mass balance, evaporation, actual evapotranspiration, and growing-season length. Despite uncertainties arising from limitations in the temporal and spatial extent of the data available for all of these variables, trends in these variables generally are consistent with an ongoing intensification of the hydrologic cycle. Of particular interest are recent studies showing that large regional and coherent changes in ocean salinity, runoff from major rivers, and glacier mass balance are all consistent with an intensification of the hydrologic cycle. However, most of the evidence indicates that the frequency and intensity of major storms, floods, and droughts have not changed consistently over the observational record.

H31F CC: 520 C Wednesday 0830h

Comparison of Aeolian and Fluvial Dynamics and Sedimentation I

Presiding: **C L McKenna Neuman,** Trent University; **P Wiberg,** University of Virginia

H31F-01 0835h INVITED

Morphologic and Dynamic Similarity of Bedforms in Fluvial and Aeolian Geophysical Flows

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Bedforms such as ripples, dunes, and low-lying bedwaves are common topographic features on river beds and wind-blown surfaces where the shear forces exerted by the fluid exceed the threshold values for particle motion. Although the fluid flows likely differ in aeolian and fluvial systems, the bedforms share many similarities including bedform size, shape, and migratory habit, boundary layer characteristics, hydrodynamic flow structure, sediment transport processes and relation of transport to morphology. However, there are also important differences. The morphologic and dynamic similarities suggest that the formative processes of bedform growth and transition in fluvial and aeolian environments are similar, yet explanations often differ between the two environments. Study of these similarities and contrasts should improve overall understanding of bedforms in geophysical flows. Here, recent work will be presented examining the similarities and differences between ripples, dunes, and low-lying bedwaves generated in these distinctly different geophysical boundary layers in a wide range of sediment sizes. The discussion will focus on: (1) boundary layer theory and bed shear stress, (2) sediment transport mechanics, (3) bedform initiation, growth, transition, and scaling.

H31F-02 0855h

Aeolian Dune Processes and Dynamics

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This paper reviews our current understanding of aeolian processes and sand dune dynamics. The main findings of three methods of investigation are briefly reviewed: field studies, wind tunnel studies, and mathematical modelling. Whilst major advances in field

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