the role of ocean is more important. The warming over the western North Pacific is crucial for the onset of Indochina monsoon, while that over the continent is important for the Indian monsoon onset. Why such difference is generated? The state of pre-monsoon rains over Indochina is also different from that over India. Periodic rains occur in April and early May in the pre-monsoon season over Indochina. These events are influenced by the invasion of mid-latitude disturbances. The major moisture for these rains comes from the Pacific, contrasting with the summer monsoon westerly flows. It is still unclear why Asian summer monsoon starts earliest over Indochina. Apparent regional differences of diurnal variations of tropical rainfall have been revealed in Asian monsoon region using minute rainfall observations, satellite remote sensing, radar observations and non-hydrostatic cloud-resolving numerical models. The diurnal eastward migrating rainfall system during summer monsoon season is investigated in Thailand. However, there are many different characters of diurnal rainfall variability in Asian monsoon region which have not been well understood. The mechanism causing above mentioned problems would be studied under CEOP integrated observational data and CIMS (CEOP Inter-monsoon Model Study).

H22I-08 1745h

Murray Darling Basin Isotope Observations: an Essential Component of the Australian CEOP

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The Murray Darling Basin Coordinated Enhanced Observing Period (CEOP) is the Australian contribution to the international effort by the World Climate Research Program (WCRP) to acquire in situ and satellite hydrometeorological data and to use these data sets to develop improved land surface process understanding in climate models. Within the GEWEX Continental Scale Experiments (CSE) system, the Murray Darling Basin (MDB) isotope collection is also co- coordinated with the International Atomic Energy Agency's Global Network for Isotopes in Rivers (GNIR). The data collection phase extends from 1 July 2002 to 30 June 2005 with a special focus on Darling River in situ reference sites. We are using CEOP data to monitor water and salt processes and to improve their representation in various atmosphere and land surface hydrometeorological models. Specifically, we find that among the 17 AMIP (Atmospheric Model Intercomparison Project) II AGCMs (Atmospheric General Circulation Models) with no reporting errors (Henderson-Sellers *et al.*, 2003) six fail to close the water balance to within ±0.05 mm d^{-1} in the Murray Darling CSE. Also seven models implausibly simulate 17-year mean evaporation greater than mean precipitation in the MDB due, to some extent, to poor soil water initialisation. Indeed, we find that soil water initialisation is a prevalent problem in all the GEWEX CSE regions. Furthermore, the non-closure of their surface water budget and very different evaporation ratios from observations suggest that reanalyses are not appropriate tools for evaluating the AGCMs' simulated surface water budget components. Due to constrained atmospheric forcing, off-line land-surface schemes, such as VIC, close the surface water balance and simulate evaporation ratios better than any reanalyses but in some regions, such as the MDB, runoff ratios are very different from observations. Here, we report on simulated and observed surface water budget components from models and reanalyses. Finally, we examine isotopes as an alternative tool for the evaluation of AGCMs' hydrometeorology.

H22J MCC: 3022 Tuesday 1600h

Hydrologic Flow Near the Earth's Surface II

Presiding: **D Barry,** University of Edinburgh**; T S Steenhuis,** Cornell University

H22J-01 1600h INVITED

Fingering and Intermittent Flow in Unsaturated Fractured Porous Media

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Because of the dominance of gravitational forces over capillary and viscous forces in relatively large fracture apertures, flow processes in unsaturated fractures are considerably different from flow in rock matrix or in unsaturated soils. Additionally, variations in fracture geometry and properties perturb the delicate balance between gravitational, capillary, and viscous forces, leading to liquid fragmentation, fingering and intermittent flows. We developed a quantitative framework for modeling fluid fragmentation and the subsequent flow behavior of discrete fluid elements (slugs). The transition from a slowly growing but stationary liquid cluster to a finger-forming mobile slug in a non horizontal fracture is estimated from the force balance between retarding capillary forces dominated by contact angle hysteresis, and the weight and shape of the cluster. For a steady flux we developed a model for liquid fragmentation within the fracture plane that gives rise to intermittent discharge, as has been observed experimentally. Intermittency is shown to be a result of interplay between capillary, viscous, and gravitational forces, much like internal dripping. Liquid slug size, detachment interval, and travel velocity are dependent primarily on the local fracture-aperture geometry shaping the seed cluster, rock-surface roughness and wetness, and liquid flux feeding the bridge (either by film flow or from the rock matrix). We show that the presence of even a few irregularities in a vertical fracture surface could affect liquid cluster formation and growth, resulting in complicated flux patterns at the fracture bottom. Such chaotic-like behavior has been observed in previous studies involving gravity-driven unsaturated flow. Inferences based on statistical description of fracture-aperture variations and simplified representation of the fragmentation processes yield insights regarding magnitude and frequency of liquid avalanches. The study illustrates that attempts at describing intermittent and preferential flow behavior by adjustment of macroscopic continuum approaches are destined to failure at most local scales. In accordance with recent observations, flow behavior in partially saturated fractures tends to produce highly localize pathways that focus otherwise diffusive fluxes (film flow or matrix seepage).

H22J-02 1620h

Dynamic Capillary Pressure Mechanism for Instability in Gravity-Driven Unsaturated Flows

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Several alternative models for describing water flow in unsaturated porous media are presented. These models are each based on an equation for conservation of mass of water, and a generalized linear law for water flux (Darcy's law) containing a term referred to as the dynamic capillary pressure. The distinct form of each alternative model is based on the specific form of expression used to describe the dynamic capillary pressure. The conventional model arises when this pressure is set equal to the equilibrium pressure given by the capillary pressure - saturation function for unsaturated porous media, and this formulation leads to the Richards Equation(RE). Other models are derived by representing the dynamic capillary pressure by a rheological relationship stating that the dynamic capillary pressure is not given directly by the capillary pressure - saturation function. Two forms of rheological relationship are considered in this manuscript, a general non-equilibrium relation, and a more specific relation expressed by a first-order kinetic equation referred to as a relaxation relation. For the general non-equilibrium relation the model equation system is called the general Non-Equilibrium Richards Equation(NERE) model, and for the case of the relaxation relation the model system is called the Relaxation Non-Equilibrium Richards Equation(RNERE) model. Each of the alternative models is analyzed for flow characteristics under gravity-dominant conditions by using a traveling wave transformation of the equations for each model, and more importantly the flow described by each model is analyzed for linear stability. It is shown that when a flow field is perturbed by infinitesimal disturbances, the RE is unconditionally stable, while both the NERE and the RNERE are conditionally stable. Instability of flows for the NERE and the RNERE models are shown to be related to the saturation and pressure profiles being sufficienlty non-monotonic. Through a nonlinear stability analysis it is shown that flows for the RE are unconditionally stable not only to infinitesimal disturbances but to finite disturbances as well for both homogeneous and heterogeneous porous media.

H22J-03 1635h

Experimental Measurements of Saturation Overshoot on Infiltration

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Gravity driven fingers in uniform porous media are known to exhibit saturation overshoot with saturated (or nearly so) tips and much less saturation in the tails. We find that constant flux infiltration into confined (smaller than the finger width) porous media produces saturation overshoot identical to that found in gravity driven fingers. Using light transmission, the saturation profiles were measured as a function of infiltrating flux, porous media grain size, grain sphericity and initial water saturation. Saturation overshoot ceases below a mininum in infiltrating flux which depends greatly on grain sphericity and initial water content and slightly on grain size. We will discuss how the measured 1-D saturation overshoot is inconsistent with continuum models of porous media, but qualitatively matches well predictions using pore filling mechanisms. This suggests that pore-scale physics controls saturation overshoot and in turn gravity driven fingering.

H22J-04 1650h

Visualization and Analysis of Multiple Fluid Phases in Sandstone for Drainage and Imbibition

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In this study, we present results on the measurements of interfacial area per volume (IAV) in a natural three-dimensional porous medium, i.e. sandstone. A set of cored sandstone samples measuring 52 mm in diameter by 100 mm or 25mm in length were used in Wood's metal injection experiments to determine IAV. A wood's metal injection method was used to solidify the non-wetting fluid, which is the metal, and ethylene glycol was used to represent a wetting phase fluid. These samples were injected under different pressures from 0.014 MPa to 0.68MPa. Ethylene glycol flow rates measurements were applied before and after the injections to find the permeability difference of the samples. To visualize different phases and determine the IAV for a sample injected with Wood's metal, images of the Wood's-metal-injected core were taken with a Scanning Electron Microscope (SEM). A custom computer code was used to analyze each SEM image to isolate the rock phase, the wetting phase (EG) and the non-wetting phase, and to calculate the interface between each two phases. Analysis of the images of the metal-injected sample of the imbibitions processes found that average interfacial length per area (ILA) values for a natural

three-dimensional system (i.e., sandstone) range from 4 to 150 per cm for the rock-metal interface and 20 to 480 per cm for the EG-rock interface, for pressures that range from 0.0134 MPa to 0.68 MPa. For the metal-EG interface, ILA values rang from 0.4 to 2.5 per cm for the same pressure range. Analysis of the images of the metal-injected sample of the drainages processes found that average ILA values of sandstone samples range from 80 to 120 per cm for the rock-metal interface and from 120 to 170 per cm for the EG-rock interface, for pressures that range from 0.0134 MPa to 0.68 MPa. For the metal-EG interface, ILA values ranged from 0.4 to 3.0 per cm for the same pressure range. The investigation also found a break though pressure for imbibition process between 0.027 and 0.034 MPa where metal saturation increases rapidly. We present the results of both imbibition process and the drainage process. Acknowledgments: Department of Energy - Fossil Energy contract DE-AC26-99BC15207. LJPN wishes to acknowledge Purdue University Faculty Scholar.

H22J-05 1705h

Horizontal Fluid Infiltration: A New Measurement Device and Some Observations

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Fluid infiltration in the vadose zone has been the subject of study since the early 1900s. Understanding infiltration processes is important to numerous problems, including forecasting moisture distribution following soil irrigation, estimating the potential for leachate generation during landfill cover design, and predicting contaminant transport to groundwater following a surface spill. Many models have been developed to describe fluid infiltration, including the well-known models by Jean-Yves Parlange and his coworkers (e.g., Smith and Parlange, Water Resources Research, 14(3), 1978). These models predict the time-rate of infiltration and the cumulative volume of infiltration based on parameters, such as sorptivity, that are often obtained from laboratory experiments. The proper design of these experiments, and appreciation of the factors controlling parameters derived from them, is therefore key to the accuracy of such models. This paper describes a new experimental setup to observe fluid infiltration under one-dimensional capillary dominated flow. Dry soil is packed in a horizontal 700 mm long polycarbonate channel that is 25.5 mm x 25.5 mm in cross-section. The top of the channel is open to the atmosphere. The upstream end of the channel is connected, via a three-valve chamber, to an infiltrant container placed on an electronic balance. Initial flooding and final draining of the three-valve chamber can be controlled without disturbing conditions in the column. The height of the infiltrant container can be adjusted to control the fluid inlet head. The end of the column is capped with a seal that allows the free exit of air. During an experiment, fluid is introduced at the upstream end of the column at a fixed head. The position of the infiltration front and the cumulative mass of fluid flowing into the column are both observed with time. At the end of each experiment, the fluid saturation along the column is obtained by sampling from the top, open surface of the column. Infiltration experiments into initially dry, uniform sand (D10 = 0.09 mm) were performed using the new setup. Either water or Soltrol 220 was used as the infiltrant. The inlet head was varied between -30 cm and 50 cm. For all experiments, a linear increase in fluid infiltration with the square root of time was observed, confirming capillary dominated flow. Results from the experiments demonstrate that the sorptivity and transmission zone saturation both increase with the infiltrant head. The results also reveal that the sorptivity of water and soltrol in a soil cannot be simply related through the fluid properties, even when the infiltrant head is zero. Both of these findings have implications for the measurement and use of sorptivity (or other related parameters) for predicting fluid infiltration.

H22J-06 1720h

Application of the Preisach Model to Soil-moisture Hysteresis

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An examination of the physics of the land phase of the hydrological cycle shows that the most important non-linearities occur in the unsaturated zone of the soil. These have been studied using switched boundary conditions applied to the one-dimensional form of Richards differential equation, modelling the wetting and drying of a column of bare or vegetated soil, at a scale of roughly one meter. However, the strongly non-linear hysteretic property of the soil moisture characteristic is usually ignored. Smooth non-linear differential, or integro-differential, operators cannot reproduce soil-moisture hysteresis. The classical Preisach Model is presented and applied to the quantitative description of soil-moisture scanning curves. The Preisach model is a deterministic, rate independent non-linear operator with return-point memory and congruent loops. Special, one parameter, classes of Preisach operators are proposed as models of soil-moisture hysteresis for particular soils. The results of fitting these operators to laboratory and field data, taken from the Grenoble GRIZZLY Soil Database, are presented and discussed.

URL: http://www.bcri.ucc.ie/BCRI_15.pdf

H22J-07 1735h

Containment of Saline Intrusion by Air Injection

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The effects of air injection on flow through porous media were explored in a series of 1 m and 2 m laboratory flow cells. Our motivation was to examine air barriers as an alternative to hydraulic barriers to retard saline intrusion in coastal areas. Steady flow conditions were created in homogeneous and heterogeneous unconsolidated sand systems. Dry air was injected at progressively higher flow rates through a well in the center of each flow cell. Discharge and NaCl-tracer concentration breakthrough data were measured at the outflow reservoir of each cell. In addition, a dye tracer was used to visualize the flow patterns. In all cases, air injection was found to produce stable, low conductivity barriers that reduced discharge by an order of magnitude or more. Effective hydraulic conductivity values determined from discharge and hydraulic head data showed exponential declines with increased air-injection rates in all cases. Numerical simulation was used to quantify hydraulic conductivity and effective porosity values in the saturated and aerated regions created by air injection, and to study advective flow behavior. Pore-filling cement formed in the air-injection region, and was analyzed to determine its composition, mass, and volume. Approximately 60% of the cement consisted of soluble minerals and 40% were less soluble carbonates. Evaporation to dryness and increase in solution pH due to stripping of CO_2 by the injected air were responsible for creating the cement. The cement occupied <10% of the pore space in the sand-cement aggregate. Both the trapped air and pore-fillings dissolved when air injection ceased, indicating that both barriers are temporary. These results serve as a preliminary proof-of-concept that air-injection barriers might effectively retard undesired subsurface flow, such as saline intrusion or contaminated groundwater.

H31A MCC: 3024 Wednesday 0800h

Early Results From NASA's EOS Aqua Spacecraft Mission III *(joint with A, OS)*

Presiding: **C L Parkinson,** NASA Goddard Space Flight Center**; D E Hagan,** Jet Propulsion Laboratory, California Institute of Technology

H31A-01 0800h INVITED

Infrared Remote Sensing Through Clouds With the AIRS-AMSU-HSB Sounding System on Aqua

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The main objective of the AIRS-AMSU-HSB sounding system on Aqua is to demonstrate accurate remote sounding of the atmospheric state in the presence of clouds. The AIRS instrument represents a breakthrough in infrared space instrumentation. The AIRS has 2378 infrared channels in the range of 3.7–15.4 microns with a nominal spectral resolution of 1200. A year after launch, the AIRS-AMSU-HSB system has demonstrated its ability of eliminating the effects of clouds on the AIRS infrared radiances (spectrum) in the presence of up to 80% cloud opacity in the AIRS fields of view. From the resulting cloud-cleared infrared radiances we have retrieved temperature profiles with radiosonde accuracy. The AIRS-AMSU-HSB instrument suite on Aqua is designed to meet both the NOAA operational weather prediction requirements as well as NASA's climate research needs. The three instrument suite will gather more accurate meteorological information about the Earth's atmosphere and its circulation than ever done before and will reduce the error of the initial sate for weather forecasting. For the first time, a satellite remote sensing instrument will achieve, worldwide, the same accuracy in temperature as currently possible only with direct measurements by balloon-borne sensors. For moisture, however, the accuracy of AIRS-AMSU-HSB will exceed that measured by balloon-borne sensors The performance of AIRS since launch has been exceptional indicating that the AIRS-AMSU-HSB instrument suite will meet or exceed its objective to deliver: Global, Day- Night, Lands-Oceans Infrared cloud-cleared Spectrum (Radiances) Atmospheric temperature profiles - 1K/1km Sea surface temperature: 0.5C Land surface temperature: 1C Infrared emissivity ratio Relative humidity profiles: 20%/1 km Total perceptible water vapor: 5% Fractional cloud cover 0.05 Cloud-top pressure and temperature Cloud spectral infrared emissivity ratio Total ozone burden of the atmosphere. In addition to several research products such as the total CO2 burden of the atmosphere, CO and CH4 profiles.

URL: http://www.jpl.nasa.gov/airs

H31A-02 0815h

One year of Monthly Images of Cloud-Filtered AIRS Data

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Since September 2002 the AIRS instrument has produced a nearly continuous record of nearly four million spectra per day. While only about 16,000 of these spectra per day, i.e. less than 1 percent of all spectra over ocean are essentially cloud-free, when agregated into monthly day/night hhhimages using 200,000 clear spectra each, they present a unique insight into remote sensing from polar orbit with hyperspectral resolution. We present 12 month sequences of images of the of observed minus predicted depth of the 791cm-1

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