daily rainfall are compared with rain gauge data collected in water management districts. Data collected by a network of rain gauges set up by the Earth Data Analysis Center show qualitatively similar seasonal and diurnal variability to TRMM observations. Infrequent TRMM sampling at these latitudes may be alleviate by the proposed Global Precipitation Mission (GPM) which will provide observations at roughly three-hour intervals.

H41E-0328 0830h POSTER

A Statistical Modelling Approach to Satellite Precipitation Monitoring

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While current satellite techniques are theoretically capable of producing precipitation estimates to image pixel resolutions, substantial spatial and temporal averaging is required to bring these products to a level of skill acceptable for hydrological modelling. Such averaging discards any information that the satellite imagery may contain concerning small-scale patterns of rainfall. The authors suggest the adoption of a statistical modelling approach to represent uncertainty in satellite precipitation estimates. Conditional probability distributions of precipitation with respect to infrared brightness temperature are used to parameterise a statistical model based on the Turning Bands Method. The model is then used to generate multiple high spatial and temporal resolution precipitation scenarios, consistent with the satellite data. These products in turn facilitate the use of ensemble hydrological model runs to determine of the impact of precipitation uncertainty on model outputs.

H41E-0329 0830h POSTER

Snow Condition Prediction With a Satellite Microwave Scatterometer

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Microwave remote sensing from satellite platforms has the potential to provide all-weather information about conditions at the land surface that affect surface hydrologic fluxes. Microwave backscatter in particular responds to the liquid moisture content of snowpacks, and a drop in backscatter of about 4dB at Ku band (1.7-2.4 cm) has been observed following thaw events. Microwave backscatter measured by sensors aboard the NSCAT microwave scatterometer(operational August 1996 to June 1997) was examined for its potential to predict melt conditions in the upper Mississippi River basin and over the BOREAS Southern Study Area in northern Saskatchewan. The Variable Infiltration Capacity (VIC) macroscale hydrology model was configured to run at 1/8th degree spatial resolution over both areas during the winter of 1996-97. Backscatter measured by the NSCAT sensor was compared with snow cover extent and liquid water content inferred from in situ observations, and from VIC model predictions. The comparisons indicate a weak day-to-day relationship between the observed and model-predicted snow surface moisture content, and NSCAT backscatter.

URL: http://www.ce.washington.edu/∼ulysses/

H41E-0330 0830h POSTER

Watershed-scale analyses of an Arctic drainage using advanced high resolution Digital Elevation Models (DEM)

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We recently analyzed a new, high resolution Digital Elevation Model (DEM) of the Putuligayuk (Put) River – a small, low-relief watershed in Arctic Alaska. Because of the numerous errors and large inaccuracy of the USGS DEMs for Alaska, and particularly for the Arctic, we have previously been unable to determine accurate watershed areas or drainage networks needed for basic hydrological analyses. In spring of 2001 we obtained a new DEM of the Put River watershed using Intermap Technologies advanced airborne Star3i X-band SAR interferometry system, which produces a 5 m posting DEM with vertical accuracies approaching 1 m. Using computational techniques, we determined the watershed area and channel networks from this DEM, and compared them to those based on the USGS DEMs, USGS DLGs, USGS paper maps, the USGS air photos used to make their maps, and the Star3i amplitude image. Watershed areas ranged from 496 to 759 km^2. Clear errors exist in the USGS DEM that make it unusable for both watershed area and channel networks; working from paper maps (either USGS or Star3i amplitudes) yield usable results but are ambiguous in such low-relief, wetland regions where substantial areas of the headwaters lack identifiable stream channels. The Star3i DEM yielded the best results, though variations in systematic noise at seam boundaries may be distorting channel routing in the headwaters. The results strongly suggest that a new topographic mapping mission in Alaska will dramatically improve our ability to model and understand the hydrological processes in the Arctic.

URL: http://www.uaf.edu/water/faculty/nolan

H41E-0331 0830h POSTER

Land Data Assimilation and Estimation of Soil Moisture Using Measurements from the Southern Great Plains 1997 Field Experiment

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Remote sensing platforms making radiobrightness measurements (in the L-band microwave frequency) provide indirect observations of surface soil moisture. But, in comparison with the natural variability in soil moisture fields, these measurements have coarse spatial resolution (tens of kilometers), and they are characterized by infrequent revisit sampling (two to three days). A truly useful soil moisture data product will require the merging of measurements and models using a data assimilation framework. In this paper we apply the Ensemble Kalman Filter (EnKF) to estimate large-scale soil moisture fields using microwave brightness temperature observations taken during the Southern Great Plains 1997 (SGP97) Experiment. The EnKF technique is appealing for several reasons: (i) its sequential nature is well suited to real-time data streams and forecasting, (ii) it not only provides an estimate of surface and profile soil moisture, but information about the statistical confidence of estimation, (iii) it is straightforward to apply with any "off-the-shelf" model, and (iv) it is relatively efficient, making its application to large-scale problems feasible. Results from the application of the EnKF using the SGP97 data include: large scale maps (∼ 10,000 km^2) of the estimated soil moisture field for the entire month-long experiment, investigation of scaling issues related to the use of coarse observations, comparison of surface soil moisture estimates to ground-truth gravimetric data, and comparison of surface flux estimates to those from flux tower stations. The soil moisture estimates from the filter are shown to be significantly better than those from an "open loop" simulation, clearly indicating the added information provided by the remotely sensed observations. Our results indicate that the EnKF not only works for the soil moisture assimilation problem, but that its potential extension to large-scale operational problems is promising.

H41F MC: Hall D Thursday 0830h

The Lake Tahoe Basin: Lessons in Lake and Watershed Science for Western North America I *(joint with B, HG)*

Presiding: **C Goldman,** University of California, Davis**; G Miller,** University of Nevada

H41F-0332 0830h POSTER

Trends in Littoral Zone Turbidty at Lake Tahoe During the Previous Decade

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A marked decrease in lake clarity over the past 3 decades at Lake Tahoe has caused both policy makers and scientists to focus their attention on preserving the exceptional clarity of the lake. It has been well established that clarity in the pelagic zone has declined by 30% during this time. However, it is unclear if similar changes have occurred in the littoral zone. While biologic activity appears to be responsible for declines in pelagic zone clarity, other factors may be influencing near-shore clarity and its inverse, turbidity. These include changes in suspended sediment loading from variations in stream discharge, wave action, lake level, and precipitation. In this study, turbidity data from a number of sites in the littoral zone of Lake Tahoe have been analyzed using stochastic methods. The analysis focused on determining if long term trends in turbidity levels in the last decade as well as relationships between environmental and climatological factors and turbidity are statistically significant.

H41F-0333 0830h POSTER

Deep Groundwater and Heat Flow in the Tahoe Basin Region

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Montane ecosystems depend on groundwater, but generally in montane areas little is known about the groundwater flow characteristics, in part due to the sparsity of boreholes in such areas. A way is needed to characterize subsurface hydrology using nontraditional approaches. We propose that thermal analysis provides a cheap and relatively easy method by which areal-scale and regional-scale groundwater flow can be characterized within montane ecosystems and other areas with high relief. The technique does not require a large number of boreholes. The technique yields information on both shallow and deep groundwater flow fields. Recent developments have substantially increased the value of the thermal analysis approach to montane groundwater flow characterization:

We will present some temperature profiles we have measured in the Tahoe Basin region. Conceptual numerical models indicate that Tahoe Basin upland temperature profiles are most sensitive to upland recharge rates in the range of 1 to 50 cm/year. Recharge rates (to depth) in the range 1 to 50 cm/year are consistent with Tahoe Basin permeabilities (at depth) in the range 0.1 to 10 mDarcy, typical of values reported for other regions of granitic bedrock.

H41F-0334 0830h POSTER

Aircraft Measurements of Gaseous and Fine Particulate Nitrogen over the Sierra Foothills and in the Tahoe Basin

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Atmospheric deposition is an important source of nitrogen (N) to the Sierra-Nevada Mountains and is one of the major causes for the shifting of the nutrient response of Lake Tahoe from N-limited to generally P-limited. Although their sources are largely unknown, airborne N received by Lake Tahoe could be either generated locally or transported from upwind areas. The Sacramento Valley, which has large vehicular and agricultural emissions of N, is possibly an important out-of-basin source. In order to explore the significance of the transport of nitrogen from the Sacramento Valley to Lake Tahoe, we have characterized atmospheric N along a transect from the Sacramento Valley to the Tahoe basin.

Gaseous and $PM_{3.5}$ samples were collected by light aircraft in three regions: in the Sierra foothills east of Sacramento ("low Sierras"), further east and higher in the Sierras ("mid-Sierras"), and in the Tahoe basin. Significant amounts of total N (gaseous + particulate) were measured over the low and mid-Sierras; the median concentration was 526 nmol N m^{-3}-air. Concentrations of total N were significantly lower in the Tahoe Basin. In all locations gas phase N, mainly in the form of NH_3, typically accounted for $\sim$ 70% of the total N.

On two sampling days in the Tahoe Basin we encountered slightly smoky conditions from upwind forest fires. Under these conditions the median concentration of total N was 267 nmol N m^{-3}-air, approximately twice the value under regular clear conditions. While the concentration of inorganic N was similar under these two types of conditions, concentrations of organic N (ON) were significantly higher in the smoky air. The average gaseous ON concentration was $\sim$ 2 times higher in the slightly smoky air compare to the clear conditions while the average $PM_{3.5}$ ON concentrations were almost 10 times higher in the smoky air.

These results suggest that the Sacramento Valley and Sierra foothills could be a source of atmospheric N under favorable meteorological conditions. In addition, our preliminary data suggest that forest fires could be an important source of atmospheric N, especially organic forms, to the Tahoe Basin.

H41G MC: 125 Thursday 0830h

Recharge and Vadose Zone Processes in Semiarid and Arid Regions II *(joint with B)*

Presiding: **F M Phillips,** New Mexico Tech**; C J Duffy,** Penn State University**; J Hogan,** University of Arizona

H41G-01 0830h

Fundamental Concepts of Recharge in the Desert Southwest

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Recharge in arid basins does not occur in all years or at all locations. To address the temporal and spatial variability of recharge, one must (1) distinguish between recharge and net infiltration, (2) understand travel time in the unsaturated zone, and (3) comprehend the local- and basin-scale deterministic processes and surficial properties that control net infiltration. Net infiltration is the quantity of water that moves below the zone of surface evapotranspiration whereas recharge is the quantity or process of water entering the saturated zone. Under steady-state conditions, net infiltration becomes recharge unless diverted to an area of spring flow, generally by laterally extensive, low-permeability rock. The rate of net infiltration, thickness of unsaturated zone, and the effective porosity of the flow-pathway control travel time through the unsaturated zone. Net infiltration and recharge vary spatially owing to variations in surface microclimates, root zone and unconsolidated material thickness, faults and fractures, and thickness and hydrologic properties of geologic strata in the unsaturated zone. Although temporal fluctuations in net infiltration diminish with depth, resultant recharge is expected to vary on timescales of days to centuries making decadal-scale climate cycles significant to understanding recharge. Results of model simulations of recharge indicate that net infiltration occurs in less than 5 percent of the area of a typical southwest basin and only when the surface-water supply exceeds the storage capacity of the root zone and evapotranspiration over a fixed period of time. The critical components controlling net infiltration and recharge are precipitation, as rain or snow (and snow accumulation and melt); infiltration and water storage capacity of the overlying soil (within the zone of evapotranspiration); potential and actual evapotranspiration; and bedrock permeability. In the desert Southwest, potential evapotranspiration exceeds precipitation on a yearly basis. However, on shorter time scales and in certain areas of a basin, precipitation and (or) snowmelt exceed the infiltration capacity of the soil and becomes runoff or exceed the storage capacity of the soil and becomes runoff in shallow soils or percolates below the root zone in deeper soils.

A method to simulate the spatial and temporal variability of net infiltration was developed using a deterministic water-balance model and extensive GIS coverages. The GIS coverages include a digital elevation model and maps of geology, soils, vegetation, precipitation, and air temperature. Other required surficial properties for the model, such as permeability, porosity, and water-retention functions, have been calculated from associated data sets. The deterministic model identifies the areas and climatic conditions that allow for excess water, quantifies the amount of water available either as runoff or in-place recharge, and allows inter-basin comparison of recharge mechanisms (i.e. mountain front, mountain block, ephemeral stream) and potential recharge for current, wetter, and drier climates. Travel time through the unsaturated zone can be estimated if unsaturated zone thickness and permeability data are available. The model, which uses a monthly time step, is being used to evaluate the role of decadal-scale climate cycles (El Niño/La Niña and the Pacific Decadal Oscillation) and recharge potential at a pixel scale (generally 30 - 90 meters) across the entire desert Southwest.

H41G-02 0845h

Monthly Regional Climate Modeling from 1930 to the Present in the Arid Southwest

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Temporal and spatial changes in recharge in the arid southwestern United States are strongly affected by variability in precipitation and air temperature. Models of spatially distributed monthly climate variables, including precipitation, average monthly minimum and maximum air temperature, and snowfall, were developed for the arid Southwest using data from 1930 to the present. Measured point data were interpolated on a digital elevation model (a model grid cell generally 30 to 270 meters) using inverse-distance and spatial gradients of previously detailed climate variables. For example, snowfall was predicted using spatial gradients in minimum air temperature, elevation, latitude, and longitude. This computationally simple technique allowed quick modeling of climate for the entire arid Southwest over decadal time scales. The model was used to evaluate regional trends for climate conditions such as the El Nino, La Nina, and the Pacific Decadal Oscillation.

Results from the precipitation model were then applied to a deterministic water balance model to estimate recharge for basins in southern Nevada. The recharge model predicted areas where precipitation and snowmelt exceeded the soil storage capacity and generated either runoff or in-place recharge. Model products of inter-basin comparisons of recharge indicated that spring snowmelt and precipitation in the Spring Valley, Nevada, during positive Pacific Decadal Oscillation and El Nino years produced the largest recharge occurrences.

H41G-03 0900h

Calibration of a Deterministic Net Infiltration Model for the Death Valley Region Using Measured Daily Stream Flows

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Recharge estimates are needed to define the upper boundary conditions for groundwater flow models used to analyze water contamination and availability in the Death Valley region of southeastern California and southern Nevada. Estimated net infiltration, where net infiltration is defined as percolation below the root zone, was used as an indicator of potential recharge. Spatially distributed net infiltration was estimated using a deterministic soil-moisture model that incorporates distributed parameters to define basin characteristics, including topography, vegetation, soil properties, and bedrock geology. Daily soil moisture, evapotranspiration, runoff, surface-water discharge (stream flow), and net infiltration (based on a maximum root zone depth of 6 meters) are simulated using the defined basin characteristics and climate input consisting of continuous records of daily precipitation and air temperature from a network of monitoring sites. The deterministic model was calibrated using a trial-and-error approach of matching simulated and measured daily stream flow records at 26 stream-gaging sites in the Death Valley region. Model parameters were selected for optimization based on high uncertainty in parameter values, and were adjusted through a range of values during the calibration process. The selected parameters were bedrock hydraulic conductivity, a root-zone available water storage term for bedrock, root density coefficients for bedrock and soils, estimates of summer and winter storm durations, soil hydraulic conductivity for stream channels, and parameters defining an empirical channel flow area function. An optimized parameter set for the Death Valley region was manually created on the basis of the collective calibration results for the majority of the 26 stream flow records. Calibration of the regional-scale net infiltration model was difficult owing to: (1) available daily climate records did not accurately define the occurrence, magnitude, and spatial distribution of localized summer thunderstorms, and did not accurately define precipitation intensity for both winter and summer storms; (2) uncertainty in stream channel characteristics, such as channel geometry and soil properties; (3) divergent surface-water flow on alluvial fans and across normally dry playa lakes. Although model calibration proved to be difficult for some storms and for some of the stream-gaging sites, the net infiltration model was found to be satisfactory in predicting the general timing and magnitude of the larger, more widespread winter storms recorded for the Death Valley region. The final set of optimized parameters was developed using only winter storm events and also using comparisons of simulated monthly and annual stream discharge with recorded discharge. The calibrated net infiltration model was applied using daily climate records from 1950 through 1999 to develop an estimate of modern climate net infiltration for the Death Valley region. The net infiltration model was evaluated by comparing simulated net infiltration with published basin-wide recharge estimates from previous studies using alternative techniques, such as empirical precipitation-recharge models and the chloride mass balance method. Results from model evaluation indicate a need to expand model calibration using additional sources of data, such as snow cover and soil moisture measurements.

H41G-04 0915h

Spatio-temporal recharge patterns in a semi-arid alluvial basin with irrigated crops

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Recharge in semi-arid regions with irrigated crops is predominantly driven by irrigation technology and cropping patterns, but also by the seasonal distribution of rainfall and the availability of irrigation water. A significant amount of basin recharge occurs from ephemeral streams and unlined irrigation canals.