functions and covariance structure of these random variables are discussed. A new chance-constrained programming variant, imbedded chance constraints, is presented. It permits the selection of non-expected-value realizations of the mean and variance estimates employed in the deterministic equivalents of traditional chance-constrained models. As well, it provides a convenient mechanism for generating constraint reliability response surfaces. A joint chance-constrained formulation is also presented.

H21B-04 0915 H

A New Procedure for Estimating Transport Loads of Trace Constituents in Streams

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A new procedure is presented for estimating transport loads of trace water-quality constituents in streams from monthly samples when some of the observed concentrations fall below the analytical detection limit of the laboratory. The new procedure employs a log-linear regression procedure for censored data, and incorporates a correction for the bias introduced by the nonlinearity of the logarithmic transformation. A linear relationship is assumed to exist between the explanatory and log-transformed load variables, and errors in log space are assumed to be normally distributed. The new procedure is evaluated by Monte Carlo simulation, and compared against a true maximum likelihood estimator in terms of bias and mean square error of the load estimate. An application of the procedure to water-quality data from the National Stream Quality Accounting Network (NASQAN) is presented.

H21B-05 0930 H

Sources of Dissolved Solids in the Upper Colorado River Basin

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Monthly and annual dissolved-solids loads and concentrations were estimated for 70 gaging stations in the Upper Colorado River Basin. From 1942 to 1983, annual loads transported from the basin averaged 8,000,000 short tons of dissolved solids, at a concentration of 550 mg/L. Mean concentrations at stations in the basin ranged from 29 to 6,700 mg/L, but did not exceed 600 mg/L in any of the major rivers.

The largest natural point sources of dissolved solids loads were from Glenwood Springs and the Paradox Basin, which contribute 700,000 tons/yr, mostly as sodium chloride. Irrigation return flows are by far the largest human source of dissolved solids. Irrigation on Mancos Shale is responsible for more than 2,000,000 tons/yr, mostly as calcium and sodium sulfate. Irrigation on Laney Shale and the Uinta Formation contributes about 460,000 tons/yr, mostly as sodium sulfate.

Leaching of soluble material from under Flaming Gorge and Fontenelle Reservoirs has added 230,000 tons/yr since construction, mostly as sodium sulfate. Construction of large reservoirs on all major rivers has reduced the annual and seasonal variability of streamflow and dissolved solids.

H21B-06 1000 H

Chemistry of rivers in Iceland.

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The average rate of chemical denudation in Iceland is about 5 times that of the continents. The weathering environment is characterized by high rainfall (40-400 cm/year), considerable relief (0-1000 m), low temperature (0-15 °C), variable soil cover and predominantly basaltic rocks, glassy and crystalline.

The rivers are spring fed (s-rivers), direct run-off (d-rivers), glacial fed (g-rivers) and mixture of the three. The chemistry of s-rivers is more stable than the one of d- and g-rivers, and the solute load is greater in s-rivers. In d- and g-rivers the concentration of solutes is higher during winter than summer, but concentration increases with increased temperature in s-rivers. The concentration of solutes does not increase with increased suspended load in the main stream of rivers in Iceland, and there is not much increase in dissolved solids down-stream in the main rivers. The partial pressure of CO_2 (pCO_2) in s-rivers is 10-100 times below the atmospheric partial pressure of CO_2, and pH is in the range of 9-10 (buffered by silica and carbon species). However, the pCO_2 of d- and g-rivers is considerable greater than the atmospheric one, and the pH of these rivers ranges from 7 -7.5 (buffered by carbon species) thus making the physical chemistry of these rivers distinctly different from the s-type. The s-rivers are thermodynamically capable of forming smectites and zeolites, whereas the others are not. No increase in e.g. Cl and Na is marked when rivers flow on land that was under sea-level at the end of the last glaciation. The $d0^{18}/0^{16}$ from the tributaries of the Nordura river, W-Iceland, which is a d-river, gets lighter as the altitude of their catchment area increases. The $d0^{18}/0^{16}$ of the main stream, at its mouth, is considerable lighter than the $d0^{18}/0^{16}$ of the tributaries near the cost. The $d0^{18}/0^{16}$ of the main stream could therefore give the weighed average height of the catchment areas at the time of sampling.

H21B-07 1015 H

Estimated Ice Volumes on Cascade Volcanoes: Mount Baker, Glacier Peak, and Mount Adams in Washington, and Mount Jefferson in Oregon

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The 1980 eruptions of Mount St. Helens removed about .1 cubic kilometers of snow and ice from the mountain contributing to the volumes of lahars and glacial floods. The resulting devastation made apparent the need for predictive water hazard analysis on other Cascade volcanoes.

In 1981, a portable radio echo-sounding unit was used to make point thickness measurements on major glaciers of Mount Rainier in Washington, Mount Hood and the Three Sisters in Oregon, and Mount Shasta in California. Glacier ice volumes were calculated from the resulting contour maps, then used to develop empirical relations for determining volumes of unmeasured glaciers. An empirical relation between volume and area, where area is multiplied by a constant and raised to a power, best estimates ice volumes for glaciers less than 2.6 kilometers in length; volumes of longer glaciers were estimated using an empirical relation between the glacier slope (measured in 300 m elevation intervals) and an estimated shear stress that was then multiplied by the interval areas.

These methods have now been applied to glaciers of Mount Baker, Glacier Peak, Mount Adams, and Mount Jefferson. Both estimation methods were employed on each of these mountains. Results indicate that Mount Rainier supports more perennial snow and ice (4.4 cubic kilometers) than all the other Cascade volcanoes combined. Mount Baker supports about 1.8 cubic kilometers. The remaining volcanoes together support less than one cubic kilometer on their slopes.

H21B-08 1030 H

Flood Regions in Kentucky Defined by Regression Analysis

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Regionalization based on residual analysis can improve the precision of regression estimates, but statistically homogeneous flood response in defined regions has been questioned. Seven areas were delineated in Kentucky as hydrologically distinct flood regions. The regions were defined using data for 266 gaging stations (mean record: 24 yrs), and residuals from regression of the 50-yr flood quantile on drainage area, a basin shape index, main channel sinuosity, and mean annual precipitation. The standard error associated with the statewide model was reduced by an average of about 25 percent by determining regression models separately for each flood region. Weighted least squares regression was used to adjust for effects of varying record lengths on the residual variance. Ratios of estimated prediction error of the weighted least squares model to that of the corresponding ordinary least squares model ranged from 0.87 to 1.05 for estimating the 2-yr to 100-yr flood quantiles.

The Wilcoxon Rank Sum test, used to compare residuals, indicated all seven regions were statistically different at the 0.10 level and four were different at the 0.001 level. Flood characteristics and factors controlling flood response were compared among the flood regions.

H21B-09 1045 H

Mapping of Southwestern Drought Using Carbon-13/Carbon-12 Ratios in Pinyon Tree Rings

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Southwestern drought has been previously reconstructed and mapped using tree-ring widths, but there is strong evidence that an additional physiological response to drought is elevated plant Carbon-13/Carbon-12 ratios, also recorded in tree rings. These ratios reflect an overall low stomatal conductance perhaps with high potential carbon fixation during drought periods characterized by abundant sunlight but low moisture availability. This study examines isotope-ratio time series up to 500 years long from pinyon pine at 12 sites representing 48 trees. Four cores were sampled from each tree and analyses were conducted on cellulose of 5-yr ring groups. As with ring widths, there are strong correlations of the short-term fluctuations in the time series between sites even widely-separated, indicating a broad regional response to climatic conditions. A spline curve was fit to each isotopic time series to remove long-term trend and generate "del indices" as a measure of severity of drought or moisture excess. Results are compared to maps of Palmer Hydrological Drought Indices and dendrohydrological drought reconstructions. Additional isotopic results from bristlecone and ponderosa pine appear to conform with the maps derived from only pinyon results.

H21B-10 1100 H

Regional Estimates of Evapotranspiration Using a Water Vapor Budget Over Complex Terrain

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Hourly values of evapotranspiration were estimated for 11 clear days using profile data from a sequence of radiosoundings over hilly terrain in the Pre-Alpine region of Switzerland. The conservation equation for specific humidity was vertically integrated over the convective boundary layer and simplified. The flux of water vapor near the inversion, E_f, was estimated by using the surface flux measured with the catchment lysimeter, E_{lys}. It was discovered that on average $E_f = 0.9\ E_{lys}$, which meant it was an important term in the conservation equation. Therefore, to employ the water vapor budget equation E_f had to be parameterized. This was accomplished by using inversion and surface layer parameters in the context of K-theory. The best results were obtained by estimating the diffusivity with the friction velocity, u_*, multiplied by the thickness of the inversion, and the gradient term taken from the inversion layer. With E_f parameterized, the correlation between the three-hourly estimates of the budget equation, E_B, and E_{lys} was fairly low (i.e., $R = 0.4$); yet the 11-day total gave less than a 10% difference (i.e., $E_B = 4.03$ mm versus $E_{lys} = 4.37$ mm). This suggests that with better resolution, that is a greater number of profiles through the day, the budget method has the potential to give reasonable results for daily and weekly estimates of regional evapotranspiration.

H21B-11 1115 H

Continuous Solute Injection and Simulation for Hydrologic Monitoring in an Acidic Mountain Stream

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Solute concentration monitoring serves as an indirect approach for certain aspects of hydrologic monitoring. Studies of hazardous wastes or acidic deposition draining directly into a stream may require hydrologic monitoring on spatial and temporal scales similar to the scales of chemical reaction. For studies in acidic mountain streams, the injected solute must remain conservative at low pH and resist sorption onto the streambed. Hydrologic information obtainable during continuous solute injection includes estimation of spatial discharge variation, temporal discharge variation, stream velocity, and solute dispersive characteristics.

In studying the dynamics of iron transport in the naturally acidic Snake River (Montezuma,Colorado) lithium, sodium, chloride, bromide, and sulfate were continuously injected to determine hydrologic transport characteristics. Analysis of lithium concentration data from a six-hour injection showed that discharge was steady temporally but increased spatially from 220 to 800 L/sec over a five kilometer reach. Comparisons based on mass-balance of the other solutes support the results of the lithium discharge analysis. Hydrologic transport parameters for the Snake River were estimated by comparing lithium data to numerical simulations which include a transient storage (dead-zone) mechanism. Further comparison of these results with simulations of the chloride and sulfate data do not indicate time-dependent reactivity for lithium in the Snake River.