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An Agrometeorological model (MAGRET) was developed to solve the energy balance over vegetated surfaces. The magnitude of surface temperature for grass and crops is the result of the energy balance and infers to the state of its water stress. The sensible (H) and latent heat fluxes (ET) are computed using the classical equations of turbulent transfer. Soil heat flux and temperature profiles in the soil computed using the Fourier equation. Solving the energy balance equation at hourly time step, net radiation, sensible, soil, Latent heat fluxes and surface temperature were derived. Model inputs are hourly and daily climatic data and parameters that describe the properties of soil and vegetation. The objective of this research is to combine the combine the model with parameters derived from NOAA AVHRR satellite for determining the evapotranspiration in regional scale. The surface temperature obtained from satellite is used to define the model parameters at meteorological stations by comparing surface temperature obtained from model and temperature obtained from the satellite. Comparing the model predicted surface temperature with satellite surface temperature, energy balance parameters are adjusted. The model was evaluated as part of the Southern Great Plains hydrology experiment (SGP97) during July in central Oklahoma over the predominantly grassland areas. The model was calibrated with data from four ET flux station and the results scaled up to the surround region. Results from the study show a good potential use of the MAGRET model for assessment of regional ET in agricultural areas.

H21H-06 1135h

High Resolution Evaporative Fluxes Over Corn and Soybean Crops from Lidar

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The Soil Moisture-Atmosphere Coupling Experiment (SMACEX) was conducted in the Walnut Creek Watershed near Ames, Iowa over the period from June 15-July 11, 2002. A main focus of SMACEX was the investigation of the interactions between the atmospheric boundary layer, surface moisture and current vegetative state. The Lidar collected data over fields of soybeans and corn, with mutually supporting measurements by the NRC Twin Otter atmospheric research aircraft, the Utah State University Piper Seneca remote sensing aircraft, two elastic Lidars, and an array of eddy covariance towers in the nearby fields. The aircraft and lidar will provide a high resolution mapping of the evaporation rate over the fields and the changes between them. A mapping of the evaporative fluxes that existed during the field campaign, with a comparison to the topology of the local area will be presented.

H21H-07 1150h

Surface Water Applications of Satellite Scatterometry

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We present an overview of the use of satellite scatterometry to detect surface water in liquid and solid phases for various regional geophysical applications. We study scatterometer/radiometer signatures of surface soil moisture with in-situ data from SCAN, Oklahoma Mesonet, and NCDC/GSOD stations. Results indicate scatterometer data can detect and inventory wet surface events due to rains to determine the regional frequency of surface water cycling. Animated time-series of scatterometer data over the SMEX (Soil Moisture EXperiment) region in mid-west US illustrate the monitoring of surface water variabilities over large scales. An automated flood processing algorithm implemented at the Jet Propulsion Laboratory (JPL) provides daily updated data over the world to the Dartmouth Flood Observatory (DFO) for early flood detections. We verify the flooded areas with MODIS clear-sky observations. We obtain weekly wetland results in Africa, Asia, North America, and South America. We show wetland monitoring results over the Eastern Arkansas - Mississippi River Valley with a comparison of the maximum extent to MODIS standard water. We investigate scatterometer signatures of snowmelt with field experiments carried out in Alaska to develop algorithms for snowmelt detection over the northern hemisphere. We present animated snowmelt results over the Lena River region in Siberia leading to floods (in 2000-2003) including the 2001 Lena Flood of the Century. Snowmelt timing parameters derived from scatterometer data are appropriate for assimilation into hydrology models for river discharge estimate and for flood forecast. We map ice cover over the Great Lakes and compare the results with observations from US Coast Guard (USCG) Mackinaw icebreaker and from a web camera on Granite Island. Over Greenland, we map and monitor surface melt areas and compare the results to in-situ measurements from the Greenland Climate Network (GC-Net). Results show extensive melt over the Greenland ice surface in 2002 in record amounts. We carried out a sea-ice mapping field experiment using the USCG Healy icebreaker over the Barents Sea in 2001. We detect a peculiar sea-ice barrier east of Svalbard, which poses hazards to ship navigation east of Svalbard. We map sea ice melt and refreezing areas by combining QuikSCAT and SSM/I products over the Arctic sea ice with verification from the Canadian C-ICE field experiment. Finally, we discuss limitations of current satellite scatterometers and the need for future advanced satellite sensors for surface-water applications.

H21H-08 1205h

Everglades' hydrology from space

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The Everglades region in south Florida is a unique ecological environment. Anthropogenic changes in the past 50 years, mainly for water supply, agricultural development and flood control purposes, have disrupted natural water flow and severely impacted the regional ecosystem. Currently, Everglades' flow is controlled by a series of structures (e.g., levies, gates), which provide a large-scale natural laboratory for monitoring and modeling wetland surface flow. Everglades' water level is currently monitored by about 100 stations, about half of which provide real-time data. We use space-based Interferometric Synthetic Aperture Radar (InSAR) to monitor water level variations in the entire Everglades region with a high spatial resolution (30 x 30 m^2). Our data consists of three 225x75 km^2 swaths of eastern South Florida, acquired in June, August and December 1994 by the L-band (1.275 GHz) JERS satellite. A comparison between the space-based InSAR observations and 28 ground-truth stage station data points shows a remarkable agreement. The most significant water level changes are observed in the northern section of the study area, known as Water Conservation Areas (WCA) 1, 2A, and 2B. Our results show dynamic water topography caused by gate operation on man-made levees. The data show up to 1 m of elevation difference across 5-15 km length scale. We detected both regional N-S unidirectional and radial topography patterns. We model the dynamic water topography using 1-D unidirectional and radial diffusion flow models. Our models allow us to determine a regional-scale flow conductivity parameter, which reflects the resistance to water flow due to vegetation. Future 2-D numerical flow models will enable us to determine local variations of the conductivity parameter as well as better tools for modeling and managing surface flow in the Everglades.

URL: http://www.geodesy.miami.edu/~amelung/everglades/

H22A MCC: Level 2 Tuesday 1330h

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Geocentrifuge Advances in Studying Subsurface Environmental Processes Posters

Presiding: **E D Mattson,** Idaho National Engineering and Environmental Laboratory**; P J Culligan,** Columbia University

H22A-0902 1330h INVITED POSTER

Centrifugally Driven Flow in Diverse Porous Media Over Wide-Ranging Moisture Conditions

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Centrifugal force has been successfully applied to measurement of saturated and unsaturated hydraulic properties of soils and rock. The basis of most methods is to apply a steady flow of water, by either a constant head or a metering pump, to a sample in a centrifuge. If the centrifugal force is great enough to constitute the dominant driving force, measurements of the steady-state flux, water content, and matric pressure can yield highly accurate values of hydraulic conductivity and water retention. The great force permits measurement of properties and conditions that are otherwise impossible or impractical. For example an experiment lasting a few days can measure unsaturated conductivity as low as 1E-9 cm/s. Our new approach expands the range of media and conditions to which centrifugal techniques are applicable, using an assessment of the deviations from steadiness that can be tolerated without appreciable loss of accuracy and a quasi-steady methodology that controls flow within acceptable limits. Secondary goals are to reduce the cost and specialized nature of the necessary equipment, and to reduce the operator time and level of training required.

Recent tests demonstrate these new techniques for carbonatic rock and other porous media. Numerical simulations predict the performance of the quasi-steady approach over a wide range of speeds and radii of rotation corresponding to various configurations, including centrifuges that are mass-produced for general laboratory use and the much larger ones designed for geotechnical applications. These simulations use a solution of Darcy's law in a centrifugal field to predict moisture conditions and net driving force within a sample, in order to assess the validity of these conditions for hydraulic property measurement. The tests and simulations show the improved techniques are useful for most porous rock and sedimentary media. With its simplified apparatus, capacity for larger samples, and the adaptability to various machines and operating conditions, the method expands the potential for exploring situations that are common in nature but have been the subject of few laboratory investigations, including macropore and fracture flow, other modes of preferential flow, and transient flow.

URL: http://wwwrcamnl.wr.usgs.gov/uzf/

H22A-0903 1330h POSTER

Evaluating Cr(VI) Partitioning in the Vadose Zone Under Variably Saturated Conditions

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A series of steady state solute transport experiments were conducted using the Unsaturated Flow Apparatus (UFA) and a vacuum-based column system using a coarse-textured, Fe-oxide coated soil material at various volumetric moisture contents ranging from 0.07-0.43. Once steady state flow was achieved with a surrogate groundwater solution, the columns were leached with a solution containing a common groundwater contaminant, hexavalent chromium, 0.1 or 0.5 mM Cr(VI), and tritium as a conservative tracer. At predetermined intervals, effluent samples were collected for Cr(VI) and tritium analysis. After full Cr(VI) breakthrough, the inlet solution was switched back to the groundwater surrogate and Cr(VI) was leached from the column. Experiment duration was much less and a greater range in water contents was achieved when using the UFA compared to the more traditional vacuum based system. Breakthrough curves were modeled using CXTFIT assuming equilibrium conditions since significant immobile water was not detected for the coarse material, based on the tritium data, regardless of the moisture content. As expected, Retardation (R) increased with decreasing water content, but water content had little effect on the calculated distribution coefficient. Despite the vast difference in residence times for the two column systems, similar levels of Cr(VI) sorption were observed, indicating that the retention mechanisms for Cr(VI) were not kinetically limited.

H22A-0904 1330h POSTER

Understanding Subsurface Colloid Behavior: A New Visualization Technique and the Application of Geo-Centrifuge Modeling

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Subsurface colloid behavior has recently drawn attention because colloids are suspected of enhancing contaminant transport in groundwater systems. To better understand the processes by which colloids move through the subsurface, and in particular the vadose zone, a new technique that enables real-time visualization of colloid particles as they move through a porous medium has been developed. This visualization technique involves the use of laser induced fluorescent particles and digital image processing to directly observe particles moving through a porous medium consisting of soda-lime glass beads and water in a transparent experimental box of 10.0cm,27.9cm,2.38cm. Colloid particles are simulated using commercially available micron sized particles that fluoresce under argon-ion laser light. The fluorescent light given off from the particles is captured through a camera filter, which lets through only the emitted wavelength of the colloid particles. The intensity of the emitted light is proportional to the colloid particle concentration. The images of colloid movement are captured by a MagnaFire digital camera; a cooled CCD digital camera produced by Optronics. This camera enables real-time capture of images to a computer, thereby allowing the images to be processed immediately. The images taken by the camera are analyzed by the ImagePro software from Media Cybernetics, which contains a range of counting, sizing, measuring, and image enhancement tools for image processing. Laboratory experiments using the new technique have demonstrated the existence of both irreversible and reversible sites for colloid entrapment during uniform saturated flow in a homogeneous porous medium. These tests have also shown a dependence of colloid entrapment on velocity. Models for colloid transport currently available in the literature have proven to be inadequate predictors for the experimental observations, despite the simplicity of the system studied. To further extend the work, the visualization technique has been developed for use on the geo-centrifuge. The advantage that the geo-centrifuge has for investigating subsurface colloid behavior, is the ability to simulate unsaturated transport mechanisms under well simulated field moisture profiles and in shortened periods of time. A series of tests to investigate colloid transport during uniform saturated flow is being used to examine basic scaling laws for colloid transport under enhanced gravity. The paper will describe the new visualization technique, its use in geo-centrifuge testing and observations on scaling relationships for colloid transport during geo-centrifuge experiments. Although the visualization technique has been developed for investigating subsurface colloid behavior, it does have application in other areas of investigation, including the investigation of microbial behavior in the subsurface.

H22A-0905 1330h POSTER

Modifications of the HYDRUS software packages for analyzing transient flow and solute transport experiments from centrifuge.

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HYDRUS-1D and HYDRUS-2D software packages (one- and two-dimensional numerical programs solving water flow and solute transport in variably-saturated porous media, respectively) were modified so that they can be used to simulate processes in a centrifugal field. These modified programs can be used to evaluate both steady-state and transient water flow and solute transport experiments carried out on soil or rock samples rotating in a centrifuge. The primary modification involves replacing the constant gravitational term in the Richards equation with a term that takes into account the rotational speed and the radius from the axis of rotation. The required modifications were made to codes for both direct and inverse analyses. The objective function in the inverse codes include both water flow and solute transport data. The soil hydraulic and/or solute transport parameters can be optimized either independently, sequentially, or simultaneously. Existing graphical user interfaces (HYDRUS-1D and 2D) can be used for preparing input and presenting output for the modified codes. A numerical technique used to obtain stable and mass conservative solutions is described. Several example of the program are presented and possible experiments are suggested.

H22A-0906 1330h POSTER

One-Dimensional Solute Transport in Variably Saturated Soil Using a Geocentrifuge Apparatus

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Solute transport data in variably saturated porous media have been difficult to obtain due to long experimental times required to conduct such experiments. Larger length scales of tens of cm require months of experimental time. These long experimental times increase the likelihood of undesirable secondary effects, such as biofouling and instrumentation failure compromising the experimental results. The geocentrifuge offers a potential experimental technique to shorten experimental time scales and thereby overcome these limitations. One-dimensional solute transport experiments (10-cm diameter by 30-cm in length) were conducted using the INEEL 2-m geocentrifuge. Potassium bromide was used as a tracer through Ottawa quartz sand to develop geocentrifuge experimental methodologies and to test a modified numerical tool to design and analyze the results from these experiments. Breakthrough curves were determined through in-flight monitoring of the electrical conductivity of the outflow at 10- and 20-"g"s. Solute transport velocity is proportional to the applied centrifugal acceleration. Breakthrough curves presented in this paper were obtained in less than 2 hours. The time it took to obtain these experimental results is inversely proportional to the applied centrifugal acceleration and is a fraction of the time that it would have taken in using traditional laboratory methods. A modified version of HYDRUS-1D was used to evaluate the solute breakthrough curves. The success of these geocentrifuge experiments suggests that the geocentrifuge technique is a practical and faster experimental methodology to complete tracer experiments in variable saturated media.

H22A-0907 1330h POSTER

Fundamental equations for fluid flow in a geocentrifuge

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There is a growing interest in the application of geocentrifuge techniques to the investigation of flow and transport in variably saturated media. This interest arises largely from the increased driving force for unsaturated flow using the geocentrifuge and the potential for completing relevant vadose zone experiments in less time than when using conventional 1-gravity techniques. Thus, the geocentrifuge technique allows investigation of material unsuitable (e.g. extremely low hydraulic conductivity) for conventional 1-gravity approaches. However, to fully realize the potential of geocentrifuge experimental approaches, the similarity and differences of fluid flow in a variable centrifugal field to a constant 1-gravity field must be understood. We have derived an expression of fluid potential that suggests that the conventional Darcy equation is not strictly valid in a centrifugal field. We have also conducted detailed analyses of the Navier-Stokes equations as applied to porous media flows within a geocentrifuge. These analyses show the relative effects that a variable gravity field, represented by the centrifugal force and the coriolis force, have on the flow fields. Nondimensionalization of the governing equations shows the role that the Ekman and Rossby numbers play in these porous media flows. This analysis provides information useful for the scaling of variable gravity geocentrifuge experiments and helps to define the theoretical limits under which geocentrifuge experiments exhibit similarity to field phenomena.

H22A-0908 1330h POSTER

Unsaturated hydraulic properties determined from geocentrifuge tests

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The geocentrifuge is a useful tool for studying flow in unsaturated soil under well-controlled, repeatable conditions. The high-gravity field generated by the geocentrifuge increases the self-weight of pore fluids to produce: (1) very low saturation conditions at high

capillary pressures, (2) a wide range of saturation profiles in multi-dimension, and (3) enhanced seepage velocities. Geocentrifuge experiments can be used to generate experimental data to validate mathematical models. However, if an unsaturated flow experiment is performed in the elevated gravity environment of the geocentrifuge, the unsaturated hydraulic properties must first be obtained at the target centrifugal acceleration. This information can be determined from relatively simple, one-dimensional column experiments and will provide the unsaturated hydraulic properties required as input into mathematical models. These one-dimensional column experiments will also provide insight into the influence of gravity on the flow field. In this study, a series of one-dimensional column experiments was performed to obtain the water retention characteristics of a uniform fine sand. Cumulative outflow and temporal changes of capillary pressures were measured during gravity driven drainage. The measured data were used as input data for an inverse analysis using HYDRUS 1-D to obtain unsaturated permeability and saturation-pressure parameters of the tested sand. The geocentrifuge experimental measurements were also compared with data obtained independently from conventional hanging-column tests. The suitability of the centrifuge test method was evaluated by comparing results from the two different experimental methods. In addition, the centrifuge experiments were conducted in different gravity fields to verify the scale similitude of the hydraulic properties in elevated gravity environments.

URL: http://www.inel.gov/env-energyscience/centrifuge/default.shtml

H22A-0909 1330h POSTER

Phase Structure in a Centrifugal Field: Impact of Capillary Heterogeneity and Angular Velocity

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We investigate the evolution of phase structure in a centrifugal field by simulating the simplest of two-phase experiments, the stabilized displacement of a denser wetting phase (e.g., water) by a lighter non-wetting phase (e.g., air) within a heterogeneous porous medium. We model this displacement (drainage) using a Modified Invasion Percolation (MIP) approach that includes both capillary forces and a stabilizing centrifugal force. We generate random fields of spanning pressures to represent capillary heterogeneity. The style of heterogeneity varies from unstructured (uncorrelated) to partially structured (layered system with a random overprint) to fully structured (layered with no random overprint). Drainage is simulated for each layered system twice: once for drainage perpendicular to layers and once for drainage parallel to layers. Our results show that the influence of capillary heterogeneity varies with angular velocity in a centrifugal field. As the angular velocity is increased, non-wetting phase invasion and phase structure become increasingly insensitive to capillary heterogeneity, regardless of its style or orientation. Higher spanning pressure variance, however, increases the sensitivity to capillary heterogeneity and leads to less drainage at a given angular velocity. In general, contact area between the wetting and non-wetting phase increases as the heterogeneity becomes less structured and decreases with increasing angular velocity. Because phase structure critically influences flow processes and petrophysical properties (pressure-saturation, relative permeability, electrical resistivity, etc.), the design of centrifugal experiments must carefully consider this interplay between capillary heterogeneity and centrifugal force.

H22A-0910 1330h POSTER

Runtime and Inversion Impacts on Estimation of Moisture Retention Relations by Centrifuge

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Standard laboratory methods in soil physics for measuring the moisture retention relation (drainage matric potential-volumetric moisture content relation) are each limited to only part of the moisture content range. Centrifuge systems allow intensive accurate measurements across much of the saturation range, and typically require much less time than traditional laboratory methods. An initially liquid-saturated sample is subjected to a stepwise-increasing series of angular velocities while carefully monitoring changes in liquid content. Angular velocity is held constant until the capillary and centrifugal forces equilibrate, forcing liquid flux to zero, and then a final average liquid content is noted. The procedure is repeated after increasing the angular velocity. Centrifuge measurement time is greatly reduced because the centrifugal body force gradient can far exceed the driving forces utilized in standard lab methods. Widely-used in the petroleum industry for decades, centrifuge measurement of moisture retention relations is seldom encountered in the soil physics or vadose hydrology literatures. Yet there is a need to better understand and improve the experimental methodology given the increasing number of centrifuges employed in these fields. Errors in centrifuge measurement of moisture retention relations originate from both experimental protocol and from data inversion. Like standard methods, centrifuge methods assume equilibrium conditions, and so are sensitive to errors introduced by insufficient runtimes. Unlike standard methods, centrifuge experiments require inversion of the angular velocity and average sample moisture content data to a location-specific pair of matric potential and moisture content values, The force balance causes matric potential and moisture content to vary with sample length while the sample is spinning. Numerous data inversion techniques exist, each yielding different moisture retention relations. We present analyses demonstrating the impact of different runtimes and different inversion techniques on estimated moisture retention parameters. Moisture retention data were collected for a number of poorly lithified sands and indurated deformed sands using the UFA centrifuge system (Conca and Wright, 1990). Parameters for the van Genuchten model were estimated for short and long runtimes with one inversion technique. Model parameters were re-estimated for one other inversion technique and a simple averaging approach which does not involve inversion. Our results demonstrate that the averaging approach greatly underestimates the van Genuchten n parameter relative to the inversion techniques. Insufficient runtimes also have a significant impact on estimated parameters. Our analysis indicates a need, barring method standardization, for practitioners to include information about inversion technique and runtime criteria when presenting centrifuge moisture retention results.

H22A-0911 1330h POSTER

Accelerated simulation of the migration of solutes in sandy soils amended by sewage sludge: Transport and retardation

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A common way to dispose of sewage sludge is to spead it on agricultural land because of its high nutrient (P, N) and org C contents. However, in addition to these beneficial components, sewage sludge can contain toxic chemicals such as heavy metals. This farming technique is relatively recent (several decades, at most) and there is still a need for information concerning the processes controlling the fate of the heavy metals in the sludge. To study how fast they migrate in the soil profile, the transfer of water and associated solutes in both unsaturated and unsaturated conditions can be accelerated by centrifugation according to the equation: tsimulated = treal * g2. (t: time). In a lysimeter study (diameter 30 cm, depth 60 cm) carried out using the CEA-CESTA Silat 265 centrifuge, we simulated, at 20 g, several months of percolation in one day. Experiments were done on cores of sandy forest soil (podzol) to which various sewage sludges (containing 2 to 12 mg/kg Cd, 20 to 120 mg/kg Ni, 50 to 465 mg/kg Pb) and simulated rain were applied. Major ions migrated at an estimated rate of 6-8.5 mm/simulated day (2-3 m/simulated year), while heavy metals (Cd, Ni, Pb) were retarded by a factor of 1.5 to 2. The retention of these heavy metals is associated with the organic C content of the soil profile (rich in the upper horizon).

H22B MCC: Level 2 Tuesday 1330h

Observations and Modeling of Land Surface Hydrological Processes IV Posters *(joint with A, B, C)*

Presiding: **V Lakshmi,** University of South Carolina**; A Cahill,** Texas A&M University

H22B-0912 1330h POSTER

Assimilation of Observed Discharge Records Into a Lumped Hydrological Model Using an Extended Kalman Filter

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The objective of this research is to investigate the possibility to improve discharge forecasts from a lumped hydrological model (TOPLATS) through the continuous assimilation of discharge observations. An extended Kalman filter is used as assimilation algorithm. Model simulations are performed over the Zwalm catchment in Belgium at an hourly time step from 1994 through 1998. A simple online routing scheme is applied to the modeled discharge values in order to allow the assimilation of the observed discharge records at every time step. The modeled soil moisture contents and water table levels are updated through the Kalman filtering procedure. The overall improvement in the modeled discharge peaks is quantified. The assimilation scheme is also run in a flood forecasting mode. In this mode, a two-month spin-up period, in which all available discharge data are assimilated, proceeds the forecasting period. The improvement in the forecasted discharge peaks, as a consequence of the data assimilation during the model spin-up, is assessed. This research is expected to lead to a framework to improve flood forecasts from lumped hydrological models, through the continuous assimilation of operational discharge observations.

H22B-0913 1330h POSTER

A 85-year Retrospective Hydrologic Analysis for the Western U.S.

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The National Climatic Data Center (NCDC) has recently created digital archives of daily climatological data (primarily precipitation and daily temperature maxima and minima) for the continental U.S. going back to the beginning of the instrumental records. Previous electronic archives were typically available only back to about 1948, with a few stations digitized back to the 1930's. We have used these data to extend our previous 50-year retrospective analysis back to 1916