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Soil property database: Southern Great Plains 1997 Hydrology Experiment

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[1] Many models used in land surface hydrology, vadose zone hydrology, and hydroclimatology require an accurate representation of soil properties. Unfortunately, existing soil property databases are limited in terms of reliability, precision, and their usefulness in evolving soil-vegetation-atmosphere-transfer (SVAT) schemes of general circulation models (GCMs) or regional-scale hydrologic models. Furthermore, not many site-specific, comprehensive soil property measurement campaigns have been carried out concurrently with large-scale remote sensing hydrologic campaigns. To better understand the complex and interdependent geophysical processes in the near surface, we conducted an extensive soil property measurement campaign during the Southern Great Plains 1997 (SGP97) Hydrology Experiment. We measured soil physical, hydraulic, and thermal properties across the SGP97 study region. The resulting soil property database not only is useful for evaluating the SVAT schemes in GCMs and other hydrologic models but also can be used as a basis for transfer function modeling, extrapolating point estimates of soil properties to larger spatial scales, testing point and nonpoint source pollution modeling, and evaluating evolving hypotheses in water and energy transfer across the land-atmosphere boundary. The complete data report [*Shouse et al.*, 2002] and raw data are available upon request from the George E. Brown Salinity Laboratory. Summarized data are given by *Mohanty et al.* [1999]. *INDEX TERMS:* 1875 Hydrology: Unsaturated zone; 1878 Hydrology: Water/energy interactions; 1833 Hydrology: Hydroclimatology; 1836 Hydrology: Hydrologic budget (1655); *KEYWORDS:* SGP97, soil properties, database, Oklahoma hydrology

1. Introduction

[2] Hydrologists have recognized the critical role of soil moisture and tried to develop models that extend the point-scale or local-scale physics of soil hydrology to the larger domains of mesoscale meteorological and global circulation models (GCMs). These models require pixel-scale information about the physical, hydraulic, and thermal characteristics of the soil in order to properly simulate soil hydrologic processes as part of the combined energy and water balances between the land surface and the atmosphere. Estimating pixel-scale soil properties is complicated because of the overwhelming heterogeneity of both the soil surface and the subsurface and the highly nonlinear nature of local-scale water and heat transport processes. A related and still largely unresolved problem is the measurement or estimation of the subsurface unsaturated hydraulic functions (the constitutive functions relating soil water content, soil water pressure head, and unsaturated hydraulic conductivity) and the soil thermal properties (heat capacity, heat diffusivity, and thermal conductivity) at different spatial scales. Although the importance of these soil properties has always been recognized, earlier large-scale hydrologic campaigns have not measured soil properties as rigorously as the other hydroclimatic driving factors such as precipitation, topography, and vegetation. Because of the lack of measured soil properties, researchers regularly approximate them in different ways and then associate any errors or uncertainties in model predictions with their soil property estimates.

[3] Soil heterogeneity affects the distribution of soil moisture through variations in texture, organic matter content, porosity, structure, and macroporosity. All of these soil properties affect the fluid transmission and retention functions. The variability in soil hydraulic conductivity and soil water retention characteristics greatly influences the vertical and lateral transmission properties. Significant soil moisture variations may exist over very small distances because of variations in soil particle and pore sizes. Additionally, soil color influences its albedo and thus the rate of evaporative drying. In a watershed-scale study in Chicksha, Oklahoma, *Hawley et al.* [1983] found significant differences in surface soil moisture due to differences in soil texture and antecedent moisture. *Brutsaert* [1982] recognized two stages of soil profile drying: (1) an atmosphere-controlled stage followed by (2) a soil-controlled stage. In the first-stage the moist soil profile can fully supply all the water demanded by the atmosphere. As the soil near the surface dries out, moisture can no longer be delivered at the rate demanded by the atmosphere. Instead, the moisture delivery rate is limited by the properties of the soil profile. *Brutsaert* [1982] notes

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that at any one point, the transition from atmosphere to soil control is rapid, but over the entire catchment the transition will be gradual. *Famiglietti et al.* [1992] demonstrated the effects of soil heterogeneity on flux rates using a distributed catchment-scale water balance model.

[4] *Entekhabi* [1994] presented a sensitivity analysis of the influence of soil texture on land-atmosphere interaction and pointed out the complex nature of the relationship. More recently, *Kim et al.* [1997] showed the impact of soil heterogeneity on the water budget of the unsaturated zone. They showed that in highly conductive soils, where evapotranspiration is limited by percolation through a lower boundary, heterogeneity increases the spatially averaged evapotranspiration relative to the uniform soil. For less conductive soils, decreasing infiltration rates due to soil heterogeneity cause evapotranspiration to become smaller. *Kim et al.* [1997] also concluded that equivalent parameters derived for the long-term average water budget are not valid for transient behavior and depend not only on the soil hydraulic parameters and their heterogeneity but also on the climate and the spatially uniform parameters. In a related study, *Kim and Stricker* [1996] showed that the effects of soil spatial heterogeneity on the water budget are stronger for a loamy soil as compared to a sandy soil. They suggested that soil heterogeneity has a greater influence in the loamy soil because most of the variation of the water budget is present at the smaller (field) scale. On the other hand, most of the water budget variation for the sandy soil occurs at larger scales and is temporally correlated to the rainfall field. These findings led them to conclude that from the perspective of the annual water budget a homogenous equivalent soil exists for the sandy soil but not for the loamy soil. Some other significant studies of the relationship between soil moisture variability and different soil properties were made by *Reynolds* [1970], *Henninger et al.* [1976], *Niemann and Edgell* [1993], *Crave and Gascuel-Odoux* [1997], and *Famiglietti et al.* [1998]. Studies [e.g., *Famiglietti et al.*, 1998] show that soil properties are equally or even more important for controlling upward (evapotranspiration) and downward (infiltration) fluxes than topography, vegetation, or precipitation, with the relative importance depending on the antecedent moisture content and the wetting or drying sequence of the soil. *Mohanty and Skaggs* [2001] also discovered the dominance of soil texture over surface slope and vegetation type in soil moisture time stability/instability features at selected remote sensing footprints during the Southern Great Plains 1997 (SGP97) Hydrology Experiment.

[5] SGP97 was sponsored by the National Aeronautic and Space Administration (NASA) and cosponsored by U.S. Department of Agriculture Agricultural Research Service (USDA ARS), National Oceanic and Atmospheric Administration, Department of Energy, National Science Foundation, and other federal and state agencies. Building upon the success of its predecessors such as the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE), and the Little Washita 1992 experiments (Washita'92 and Washita'94), the SGP97 Hydrology Experiment was an interdisciplinary investigation conducted by scientists working in the area of hydrology, soil science, boundary layer meteorology, atmospheric science, and ecology. The experiment covered a region of approximately 40 km × 250 km (10,000 km^2) in the subhumid environment of Oklahoma. Soil moisture data were collected over a one-month period between 18 June and 17 July 1997 using remote sensing and ground-based techniques. We conducted an extensive soil property measurement campaign during the SGP97 hydrology experiment. Our major objectives included measuring soil physical, hydraulic, and thermal properties across the Southern Great Plains 1997 study region. The resulting database serves as a basis for developing pedo-topo-vegetation transfer function models for extrapolating point estimates of soil properties to larger scales, testing surface and subsurface hydrologic and contaminant transport modeling, and evaluating evolving hypotheses in water and energy transfer across the land-atmosphere boundary within the context of regional-scale hydrology and soil-vegetation-atmosphere-transfer (SVAT) schemes in GCMs.

2. Sampling Plan

[6] We collected soil cores from different depths at representative (soil, topography, and vegetation) sites based on a priori information (gleaned from digital maps and overlays available from Earth System Science Center, Pennsylvania State University, at http://www.essc.psu.edu/nasa_lsh/) and concurrent site inspection. Although in the database we provided more detailed and unbounded site classifications for future researchers, various combinations among soil texture (12 USDA classes, see Figure15-03 of *Gee and Bauder* [1986]), relative position (valley, hillslope, hilltop), and vegetation type (grass, shrub, crop) were used as the primary groups for our site selection protocol. A total of 157 surface soil cores were collected from 46 quarter sections within the Little Washita (LW), El Reno (ER), and Central Facility (CF) intensive study areas (Figure 1). In addition to the surface cores, four or five subsurface soil cores were collected at depths of up to 1 m at selected sites (based on soil morphologic characteristics) within the LW, ER, and CF areas. Soil cores were analyzed in the laboratory for soil particle size, bulk density, organic carbon, soil water retention, dynamic outflow, saturated and unsaturated hydraulic conductivities, thermal conductivity, heat diffusivity, and heat capacity. Selected soil cores were also used to measure soil water hysteresis (drying versus wetting) and the effects of temperature on the hydraulic properties.

3. Site Description and Field Procedures

[7] The SGP97 region covers a 40 km × 250 km area within the central part of the U.S. Great Plains. The climate is classified as subhumid with a north-south precipitation gradient [*Famiglietti et al.*, 1999]. The topography of the region is moderately rolling. Soils include a wide range of textures with large areas of both coarse and fine textures (State Soil Geographic Database (STATSGO) and Soil Survey Geographic Database (SSURGO), Natural Resources Conservation Service). Rangeland and pasture with significant areas of winter wheat and other crops dominate land use. Additional background information on the Little Washita watershed in the southern part of the SGP97 region is given by *Allen and Naney* [1991] and *Jackson and Schiebe* [1993]. Other relevant surface hydrometeorological, vegetation, soil, and topographic information for the SGP97 region are given by *Southern Great Plains 1997 Science Team* [1997].

[8] Soil cores (in brass cylinders, 5.3 cm diameter and 5.9 cm long) at different depths were collected from representative (soil, slope, and vegetation) sites guided by thematic maps created using geographic information systems overlays. A pickup-truck-mounted Giddings drilling rig and a hand core or bulk density sampler were used to extract soil cores. The Giddings rig was used to extract profile core samples that were on the order of 100 cm or slightly longer. These core samples were used to tentatively classify the soil profile and determine the location of each soil horizon on the basis of field morphology (primarily texture and color). Other features that we looked for in terms of stratifying the soil horizons were wormholes or animal burrows, root channels, and macroporous

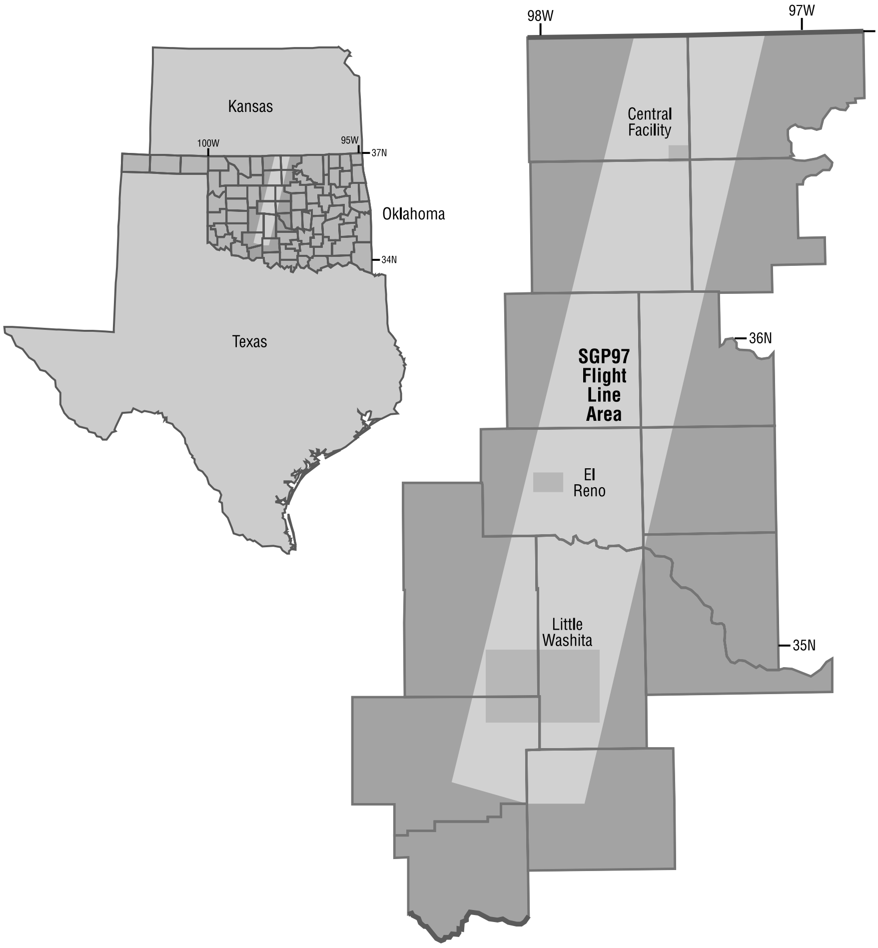

Figure 1. Geographical location of Southern Great Plains 1997 Hydrology Experiment in Oklahoma. The light gray window (40 km × 250 km) indicates the SGP97 flight line area for remote sensing measurements of soil moisture. Little Washita watershed in the south, El Reno in the center, and Central Facility in the north are the SGP97 focus regions for ground data collection and validation activities. See color version of this figure at back of this issue.

anomalies. We observed and noted the extent and density of the root systems. We took soil surface (3–9 cm depth) samples from 46 out of a total of 48 quarter sections (800 m × 800 m) in the LW, ER, and CF intensive study areas. Using a priori information and field site confirmation, one or more representative soil cores were collected from each quarter section, with additional subsurface soil cores retrieved (based on soil stratigraphy) from depths up to 1 m at selected sites. A total of 157 cores were collected. Once the soil had been classified and the depths of the different soil horizons had been defined, we sampled the depth increments for subsequent hydraulic property determination. For this purpose we excavated the soil above a particular depth with a large soil probe (6–9 cm OD) attached to the Giddings rig and then took an ‘‘undisturbed’’ soil core using the bulk density sampler. Each soil core was encapsulated in a 5.3 cm ID by 5.9 cm long brass ring (within the sampler). The brass rings were customized to fit inside the available Tempe cell apparatus (to be discussed in section 4). At all but 12 locations we collected duplicate soil samples (approximately 300–500 g for each sampled depth) in order to measure field soil water content, soil organic carbon, and particle size distribution in the laboratory. Soil temperature was measured in the field at different depths using a thermocouple thermometer (Baranant 100, model 600–2820, Industrial Instruments and Supply, Southampton, Pennsylvania) with a readout unit. Other pedological information such as soil color and structure were determined during the soil core extraction process. Correspondingly, the local (30 m diameter) topography, including the east-west and north-south slopes, was measured with a hand level (Abney Level, PECO). General landscape, relative field position, microtopography, vegetation type, canopy height, canopy density, rooting depth, current weather, and other site-specific observations were determined by visual inspection. Each sampling location was identified with a differential global positioning system (DGPS) having a precision of ±10 m. On several occasions some field data could not be measured or recorded because of technical difficulties.

4. Laboratory Measurement Methods

[9] For the sake of brevity we summarize here the important points of our laboratory procedures. Detailed descriptions of the methods are given by *Shouse et al.* [2002] and *Mohanty et al.* [1999].

4.1. Physical Properties

4.1.1. Particle size distribution. [10] A complete particle size distribution function (composed of ∼18–21 data points) for each soil sample was measured. The basic hydrometer method outlined by *Gee and Bauder* [1986] was used to determine the silt and clay fractions from approximately 50 microns to 1.4 microns. The same sample was used for determining the sand fractions between 2000 microns and 50 microns using a wet sieve method.

4.1.2. Bulk density. [11] The core method [*Blake and Hartge*, 1986] was used to measure the bulk density. In most cases we obtained at least two different estimates of the bulk density for each sample location and depth. The average of these two estimates is reported. Total soil porosity [*Danielson and Sutherland*, 1986] for each sample was calculated using the measured bulk density of the sample and a particle density of 2.65 g/cm^3.

4.1.3. Soil organic carbon. [12] Soil organic carbon content was measured directly by furnace combustion at 375°C using a UIC Full Carbon System150 with a CO_2 coulometer 5011 (UIC Inc., Joliet, Illinois).

4.1.4. Soil structure and color. [13] Soil color, structure, and other pertinent profile data were gathered during soil coring with the truck-mounted Giddings probe. A Munsell soil chart was used to identify soil color under wet and dry conditions. Soil structure was defined by manual and visual inspection. This method is limited to soil coring (based on various practical issues); however, it must be noted that soil structure can be best described by opening a soil profile.

4.2. Hydraulic and Thermal Properties

4.2.1. Saturated hydraulic conductivity. [14] We used a constant head permeameter to measure the saturated hydraulic conductivity as described by *Klute* [1986]. To reduce air entrapment, we used a dilute calcium chloride solution instead of water for these measurements.

4.2.2. Soil water retention. [15] The soil water retention curve was measured using a combination of measurement techniques. We used Tempe cells [*Reginato and van Bavel*, 1962; *Klute*, 1986; *Eching et al.*, 1994] for retention measurements between 10 cm and 500 cm of pressure head and used the pressure plate apparatus [*Klute*, 1986] for measurements at 333, 500, 1000, 3000, 8000, and 15,000 cm of pressure head. The method is detailed by *Klute* [1986]. The equilibration time varied between 10 and 60 days depending upon the texture of the soil and the pressure head.

[16] An important new feature of our measurement method was a semiautomatic Tempe cell that was used to control and record the simultaneous measurement of 22 Tempe cells. The apparatus produced a series of outflow data as a function of time. The cumulative outflow was recorded every 6 min using a data acquisition system and pressure transducers calibrated to measure water volumes (dynamic outflow). We allowed the outflow to cease completely before changing to a higher pressure. With this approach we measured the dynamic multistep outflow as well as an equilibrium retention point. The dynamic outflow data can be analyzed using inverse procedures to calculate the soil hydraulic parameters. The more conventional static measurements can be used to help refine the inverse problem, thereby lessening nonuniqueness problems and improving convergence. Static retention measurements are available for all 157 soil cores while dynamic outflow data are available for approximately 127 soil cores. Dynamic outflow data for the other soil cores were not obtained because of variety of reasons, including technical difficulties during the laboratory measurements. All water retention and dynamic outflow measurements were accomplished within a period of 2 years.

4.2.3. Soil water retention (hysteresis). [17] Forty-four samples were selected for measurement of soil water retention hysteresis. We measured hysteresis using Tempe cells. Each core was equilibrated at 500 cm pressure head following the drainage sequence, after which the pressure was decreased sequentially for imbibition to occur until the core was again saturated. The dynamic inflow rate was measured in exactly the same manner as the outflow, and a mass balance equation was used to calculate the water content.

4.2.4. Soil water retention (temperature effect). [18] The same 44 soil cores were used to measure the temperature dependence of the soil water retention curve. This consisted of measuring the retention at 20°C, 25°C, and 30°C by changing the room temperature before the cores were allowed to saturate. The equilibration time was 24 hours. The dynamic outflow was measured, and the mass balance was again used to calculate the water content of the cores.

4.2.5. Saturated hydraulic conductivity (temperature effect). [19] In addition to soil water retention, we also measured the saturated hydraulic conductivity for selected soil cores at 20°C, 25°C, and 30°C room temperatures.

4.2.6. Heat transmission. [20] We used the dual-probe heat pulse technique of *Bristow et al.* [1994] to measure heat transmission in the soil cores. A heat pulse was generated by applying a voltage from a direct current source to the heater for a fixed period of time (8 s). We used a CR7 (Campbell Scientific Inc., Logan, Utah) data logger to control the heat pulse, monitor the current through the heater, and measure the temperature of the sensor as a function of time. The dynamic temperature data were used to estimate the soil thermal properties using a numerical inversion procedure developed by *Welch et al.* [1996].

5. Data Quality

[21] We took care to assure good and consistent quality of our entire soil property database. Some important quality control measures include the following: (1) replicate sampling, (2) very fine time resolutions, (3) multiple operators verifying each others' data, (4) state-of-the-art experimental facilities including humidity and temperature control rooms, and (5) verification of mass or energy balances within reasonable limits.

6. Data Analyses

[22] In sections 6.1–6.3 we provide few typical examples of the uses for our SGP97 soil property data.

6.1. Example 1: Particle Size Distribution and Pedo-Transfer Function

[23] Our 18–21 point particle size data were grouped into sand (<2000–50 μm), silt (50–2 μm), and clay (<2 μm) fractions according to the USDA standard. The grouped data (% sand, % silt, and % clay) were used to derive the textural class of each soil sample according to the USDA textural triangle [*Gee and Bauder*, 1986]. Soil textural distributions at LW, ER, and CF are shown in a USDA textural triangle in Figure 2. Evidently, there is a wide range of textural classes represented by the samples. Sand contents range from 15 to 95%, and clay contents range from 2 to 50%. Also apparent from Figure 2 is that the Little Washita watershed contains soils with much more variation in texture than the El Reno or Central Facility locations. In general, Little Washita watershed soil texture ranged between sand, loamy sand, sandy loam, loam, and silt loam.

[24] Soil water retention or hydraulic conductivity functions can be predicted from particle size distribution data using pedo-transfer functions (PTFs) [e.g., *van Genuchten et al.*, 1992; *Tietje and Tapkeenhinrichs*, 1993], which can be directly applied in a wide range of hydrologic models. One of the early PTF studies was by *Arya and Paris* [1981], who presented a model for predicting the

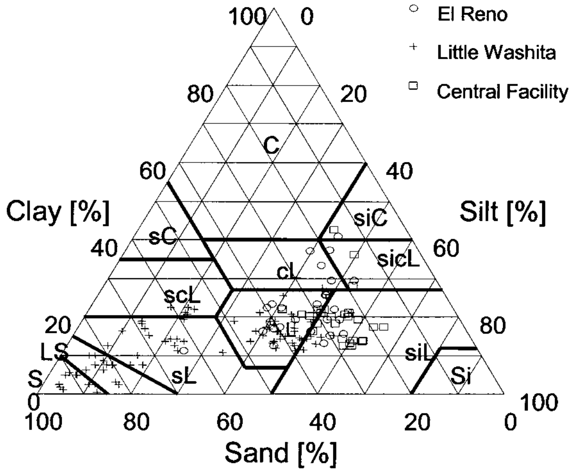

Figure 2. Soil texture distribution across the LW, ER, and CF focus regions based on particle size distribution measurements of the 157 soil samples.

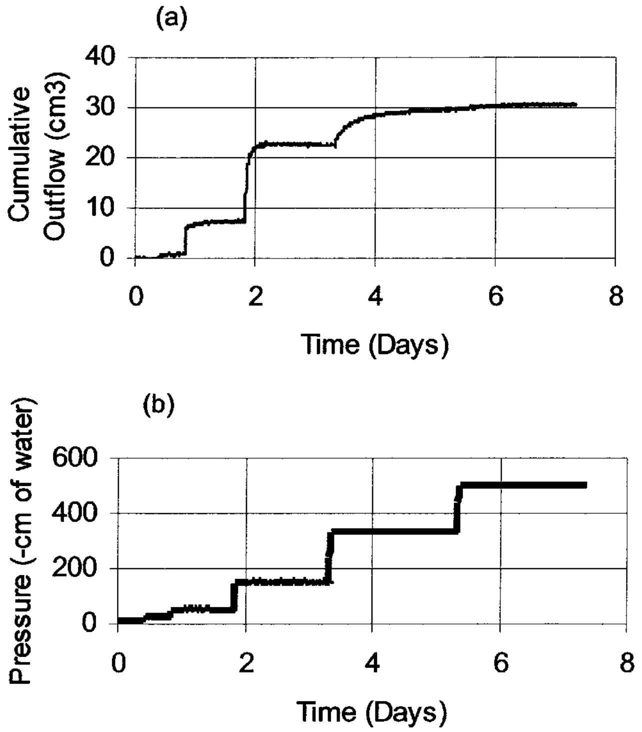

Figure 4. (a) Sample dynamic outflow data for soil sample 24 and (b) corresponding dynamic pressure steps. Total number of data points on each curve is 2126.

water retention curve from the particle size distribution, bulk density, and particle density. Their approach has been extended and modified by many researchers. Among others, *Schaap and Bouten* [1996] used neural networks (NNs) to model the drying water retention curve from particle size distribution, soil organic matter content, and bulk density. In a follow-up study, *Schaap et al.* [1998] showed improved accuracy by using a hierarchical NN-based approach with an increased number of input parameters. Our SGP database is well suited for developing hierarchical PTFs for a hierarchy of spatial scales (e.g., quarter section, watershed, and region). Combining collocated topographic and vegetation data with basic soil property data may further improve the accuracy of soil hydraulic property estimation by extending PTFs to pedo-topography-vegetation-transfer functions (PTVTFs).

6.2. Example 2: Water Retention, Dynamic Outflow, and Estimation of Soil Hydraulic Functions

[25] Computer models are routinely used to simulate water flow in the vadose zone and across the land-atmosphere boundary (e.g., SVAT schemes). Closed-form expressions [e.g., *van Genuchten*, 1980; *Brooks and Corey*, 1964] have been widely employed to describe the unsaturated soil hydraulic properties for various reasons including the following: (1) They are attractive to model the $\theta(h)$ and $K(h)$ or $K(\theta)$ relationships in numerical models, (2) nontabular data simplify input to computer models, and (3) hydraulic properties can be estimated using inverse procedures.

[26] We used our dynamic outflow and static retention data in the HYDRUS-1D inverse modeling procedure [*Šimunek et al.*, 1998] to estimate the van Genuchten-Mualem hydraulic parameters [*van Genuchten*, 1980] for each soil core. Example water retention (Figure 3), dynamic outflow (Figure 4a), and corresponding pressure-time (Figure 4b) data are presented. The inverse optimization procedure was based upon minimization of an objective function that expresses the discrepancy between the observed values and the predicted system response in terms of cumulative outflow and/or soil water retention. Initial estimates of the optimized hydraulic parameters were iteratively improved during the minimization process until a desired degree of precision was obtained. We performed the inverse optimization procedure twice with (1) equal weights for both dynamic flow and static retention data and (2) double weights for the static retention data as compared to the dynamic outflow data. For the soil cores with no dynamic outflow data we used the RETC estimation procedure [*van Genuchten et al.*, 1991] for estimating the soil hydraulic parameters from the retention data only (no value of K_s could be estimated in this manner). The *van Genuchten* [1980] functions contain six independent parameters: θ_r, θ_S, K_S, α, n, and l. During

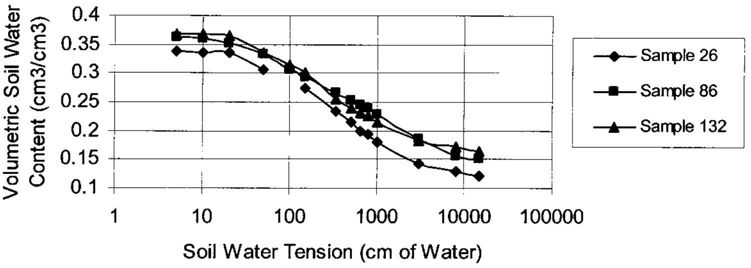

Figure 3. Soil water retention data for three soil samples (samples 26, 86, and 132) between 0 and 15,000 cm soil water tension.

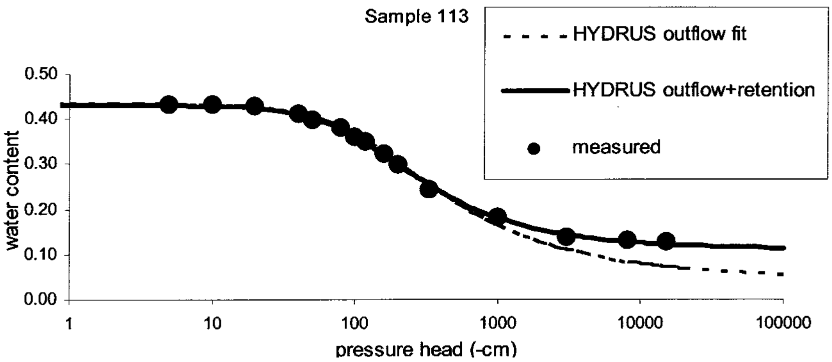

Figure 5. Comparison of measured and optimized soil water retention curve(s) with HYDRUS-1D inverse modeling procedure using (1) only dynamic outflow data and (2) dynamic outflow and soil water retention data.

the inverse optimization procedure, goodness-of-fit was quantified by the value of the objective function Φ being minimized and the r^2 value for regression of observed versus fitted values. For soil cores where both dynamic outflow and retention data are available, two sets of optimized parameters (θ_r(WCR), θ_S(WCS), K_S(CONDS), α(ALPHA), n(N), and l(L)) with goodness-of- fit values (Φ(SSQ), r^2(RSQ)) are reported in the summarized database [*Mohanty et al.*, 1999]. A single set of retention parameters is available for soil cores without dynamic outflow data where K_S(CONDS = 1.0) and l (L = 0.5) were fixed. Soil water retention functions estimated from combined dynamic outflow and static retention data fit the measured retention curves better than functions estimated from dynamic outflow data alone (see example shown in Figure 5). The use of both dynamic outflow data and static retention data in the inverse procedure helps constrain the inverse procedure in the dry end of the curve. These optimized van Genuchten parameters can be used directly in a soil hydrology component of SVAT schemes for the SGP97 study area. The parameters for *Brooks and Corey* [1964] and other hydraulic functions can be similarly optimized from our soil water retention and dynamic outflow data as necessary.

6.3. Example 3: Soil Thermal Properties

[27] Using the HPC inverse optimization procedure [*Welch et al.*, 1996], we estimated soil thermal properties on the basis of the dual-probe heat pulse data. The computer model allows for simultaneous estimation of the volumetric heat capacity ρc, the thermal diffusivity κ, and the thermal conductivity ($\lambda = \rho c\kappa$). The parameter estimation scheme requires extraction of the temperature maximum T_m and the time needed to reach the maximum temperature, t_m, from a temperature-time record. The constants T_m and t_m are subsequently used in a heat conduction model for an infinite line heat source in order to determine ρc, κ, and λ. The approach involves a "single-point" parameter estimation scheme since the model is fitted to the data at a single point, the maximum temperature. With only a few exceptions the heat pulse data and model were in good agreement, suggesting that reasonable estimates of the soil thermal properties were generated.

[28] The database has many more potential uses in surface and subsurface hydrologic modeling. The database can be used to test models of water and energy dynamics at the land-atmosphere boundary, as input to data assimilation schemes, for calibration/validation of land surface data products of airborne and spaceborne remote sensors and for nonpoint source contaminant transport studies in the southern Great Plains region. Assuming that the soil properties in our database are static (i.e., independent of time), the database can be used with remotely sensed data sets collected in the southern Great Plains during Washita'92, Washita'94, SGP97, and SGP99, as well as forthcoming missions (e.g., the planned Soil Moisture (SMEX) campaigns of NASA and others). Data from other historical field campaigns are located at the NASA Goddard Space Flight Center Distributed Active Archive Center Web sites. While our SGP97 database was developed in a focused region using consistent methods throughout, few other soil property databases developed in the United States and Europe, based on volunteer contributions from different researchers, need a mention here. For example, Unsaturated Soil Hydraulic Database (UNSODA), by F. J. Leij, W. Alves, and M. T. van Genuchten, USDA ARS Salinity Laboratory, Riverside, California, was developed in the United States, and Grizzly Soil Database, by R. Haverkamp, C. Zammit, and F. Bouraoui, Laboratoire d'Etude des Transferts en Hydrologie et Environnement, Grenoble, France, and Hydraulic Properties of European Soils Database (HYPRES), by H. Woesten and A. Lilly, Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO), Wageningen, Netherlands, were developed in Europe. In a more recent effort, joint contribution from various U.S. and European agencies has created a Global Soil Data Task, assimilating data from various sources. These data are distributed by International Geosphere-Biosphere Programme, Toulouse, France, and are available at http://www.meteo.fr/cnrm/igbp/. As the sources of data in various databases cover a wide range of soils, hydrogeologic conditions, and measurement methods, proper pretreatment and quality check are warranted before their use. Further details of some of these databases and associated research efforts were compiled by *Bruand et al.* [1996] and *van Genuchten et al.* [1999].

7. Summary

[29] A much-needed comprehensive database of soil physical, hydraulic, and thermal properties across the SGP97 hydrology study region has been developed. The data can be used for developing and testing evolving hypotheses in soil hydrology, SVAT schemes in GCMs, calibration/validation of remote sensor(s) land surface data products, and contaminant transport studies at various scales.

8. Data Files

[30] Summary data files of the soil physical, hydraulic, and thermal properties, associated topographic and vegetation data, and

other ancillary information are available in Excel spreadsheets from *Mohanty et al.* [1999]. Raw dynamic outflow data, soil water retention data (including hysteresis and temperature effects), and particle size distribution data are given in the report by *Shouse et al.* [2002], which is available upon request. Data are organized by ascending sample identification (1, 2, . . ., 157). Corresponding quarter section identification (LW1 to LW23, ER1 to ER16, CF1 to CF9), allocated site number (1, 2, . . .), and/or their geographic location (latitude and longitude) are also tagged.

[31] **Acknowledgments.** The help of many SGP97 participants in the field data collection is acknowledged. This study was funded by NASA Land Surface Hydrology Program grant NAG5-8682.

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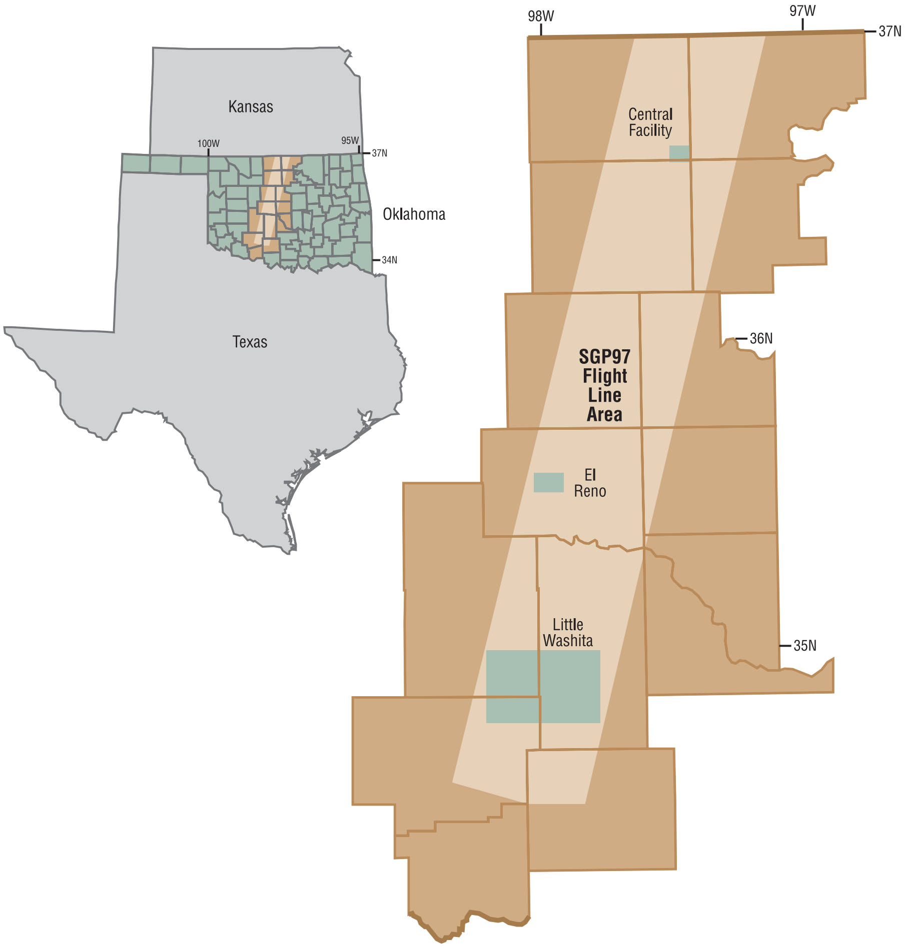

Figure 1. Geographical location of Southern Great Plains 1997 Hydrology Experiment in Oklahoma. The light gray window (40 km × 250 km) indicates the SGP97 flight line area for remote sensing measurements of soil moisture. Little Washita watershed in the south, El Reno in the center, and Central Facility in the north are the SGP97 focus regions for ground data collection and validation activities.