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Based on the determination of the zero-flux plane, a water balance procedure for large-scale experimental databases was automated to estimate the soil water balance based on soil water content distribution with depth through time. The automated procedure was verified using data from the BOREAS project obtained in three Intensive Field Campaigns during the spring and summer of 1994. The data used correspond to four tower sites measuring atmospheric fluxes above the forest canopy from the Northern and Southern Study Areas and are designated according to the predominant vegetation in the area as Old Jack Pine and Young Jack Pine.

The total hydraulic head through time at these sites is determined to identify the position of the zero-flux plane, which separates that part of the soil profile in which water flow is upward from the region in which the water flow is downward. In conjunction with precipitation and soil water content data, the procedure allows estimation of the actual soil water balance, the water used from the region above the zero-flux plane being evapotranspiration, and the change in soil water content below the mean zero-flux plane being drainage. Prior to this study, no published attempt had been made to automate a water balance procedure for large-scale experimental databases based on the position of the zero-flux plane and soil water content distribution through time.

Automated Water Balance Procedure for Large-Scale Experimental Databases Based on Soil Moisture

by

Susana Maria Grayson

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Susana Maria Grayson, Author

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DEDICATION

I would like to dedicate this thesis to my cousin Ronald "Ronny" Pearson, who died when the sightseeing plane carrying him and his close friend Alan Lawrence "Larry" Schechter crashed into an Alaskan mountainside. Their deaths left a terrible void in me and came as a shock in the lives of those who loved and were loved by them. Ronny enjoyed the theater and travel, and was an avid bridge player; Larry hiked the Himalayas, explored the Mayan ruins, rafted waterways and traveled throughout the world. Ronny and Larry's countless family members and friends will miss their love, warmth, loud laughter, endless curiosity, tremendous passion for life, honesty and decency. Together, they attacked all challenges in life with zeal, standing by as friends and warriors no matter what the fight. Their devoted friendship and support helped shape many lives, and will continue to do so.

Ronny studied sociology, community administration and law earning a bachelor's degree cum laude, a master of science degree in community and regional planning and a law degree. He served as Director of Planning and Marketing Services at Brackenridge Hospital, Austin, and practiced with the law firm of Wood Lucksinger & Epstein, Houston. He was General Counsel for TME, Incorporated and later joined the law firm of Jenkens & Gilchrist. Ronny was a member of the Health Lawyers Association, the American Bar Association, its Corporate Law Section and its Forum Committee on Health Law, the State Bar of Texas and its Business Law and Health Law Sections and the Houston Bar Association. He was Chairman of the Board of

Trustees of the Executive and Professional Association of Houston. He was a leader of HATCH, the Assistance Foundation, and the Texas Human Rights Foundation.

Larry served as president of the Texas-Oklahoma Federation of Temple Youth, and taught Sunday School at Congregational Bath Israel in Austin. He graduated with honors from the University of Texas at the University of Texas School of Law and obtained a Master's degree in Political Science at Columbia University in New York. He was a respected trial lawyer, author of law review articles, papers, and a speaker at national seminars. Larry was a respected intellect. At the time of their deaths, Ronny was a shareholder in the Health Law Section of Jenkens & Gilchrist, and Larry a partner in the law firm of Stern, Gordon & Schechter.

AUTOMATED WATER BALANCE PROCEDURE FOR LARGE-SCALE EXPERIMENTAL DATABASES BASED ON SOIL MOISTURE

INTRODUCTION

Water Balance in a Soil Profile

To automate a dependable and verifiable physically-based soil-water dynamics simulation model for a region, both the interaction of the soil moisture with the atmospheric boundary layer as well as the characteristics of the soil medium itself must be quantified (Cuenca, 1987). Soil water content in the upper few meters of the soil profile and the location of the root zone are essential in partitioning the diurnal energy balance at a site and the resulting interaction of the atmospheric boundary layer. Proper quantification of soil water content and soil hydraulic gradients which control the rate of moisture movement within the top several meters of the soil profile are essential to accurately simulate a model of the water demand by plant root processes and the interaction with the atmospheric boundary layer. In automating the water balance procedure, the various moisture inputs and outputs in the soil profile are accounted for, which includes input of moisture in the form of precipitation and surface runoff during surplus moisture periods and releases of moisture in the form of evapotranspiration, interflow and baseflow.

In periods of drought, precipitation is less than the potential evapotranspiration and all the precipitation is available to partially satisfy the evapotranspiration demand in an area. The result is termed actual evapotranspiration. If precipitation exceeds potential evapotranspiration, the soil water content increases.

Evaporation from the soil and free standing water surfaces along with transpiration from plants is referred to as evapotranspiration. Potential evapotranspiration is the amount of water that would evaporate or transpire if water was available to the plant in an unlimited supply and depends on many factors including the atmospheric demand for water in a region (Cuenca, 1989). Thus, there is a clear distinction between actual and potential evapotranspiration in a region.

The soil profile is composed of two zones, the *vadose zone* corresponding to the unsaturated portion of the soil profile and the *phreatic zone* corresponding to the saturated soil. Expressed as a percent, the degree of saturation of a unit volume of soil is the ratio of the volume of water to the volume of voids (Cuenca, 1988). The moisture content expressed as a percent, θ, is the volume of water divided by the total volume of the sample. The capillary zone rises to a certain height above the top of the saturated soil profile. Because of an unbalanced molecular attraction, surface tension acting parallel to the water surface between the soil particles is the driving force responsible for this rise (Brooks and Corey, 1964). Water in the form of thin films above the capillary zone adheres to the pore linings and drains downwards under the force of gravity. The water table is the underground water surface at which pressure is equal to atmospheric pressure.

An intermediate plane, known as the zero-flux plane, separates the region where water flow is upwards from the region where the flow is downwards in a soil profile. In areas of high precipitation or in arid regions, the zero-flux plane can be at the soil surface or below the zone of measurement, respectively. In sites with multiple precipitation events alternating with periods of drought, there may be multiple zero-flux planes determined by examining total hydraulic head data (Goutorbe et al, 1989). In such cases, updated values of the zero-flux plane are necessary to determine the portion of the soil profile that is actually contributing to evapotranspiration and drainage.

Experimental Field Site and Data Description

The BOReal Ecosystem and Atmospheric Study (BOREAS) was a joint American-Canadian-European project carried out over the Boreal Forest in the provinces of Saskatchewan, north of Prince Albert near Candle Lake, and northern Manitoba near the town of Thompson in Canada. The major experimental effort, divided into three Intensive Field Campaigns (IFC), took place during the 1994 growing season from May until September and centered around flux towers to measure atmospheric fluxes above the forest canopy. The IFC's were approximately three weeks in duration, ranging from days of year 145 through 167 in the first campaign, 201 through 231 in the second campaign, and 236 through 261 in the third campaign. The BOREAS project included ten measurement sites separated into the Southern and the Northern Study Areas (SSA and NSA), and designated according to the predominant vegetation type in the area. This study focuses on data obtained during these campaigns in both the Southern and the Northern Study Areas at the Old Jack Pine (OJP) and Young Jack Pine (YJP) sites.

Water content in the soil profile was monitored using neutron probes (Campbell Pacific Nuclear 503 Hydroprobe) in aluminum access tubes and time domain reflectometry meters with segmented rods (Environmental Sensors MP917 meter and Type A rod). Soil water content was monitored by neutron probes on an every-other-day basis during the IFC's at the Old Jack Pine and the Young Jack Pine sites in both the Northern and Southern Study Areas. Measurements were made at 10 cm intervals starting at a depth of 5 cm down to the bottom of the access tubes which extended to 165 cm at the Old Jack Pine site in the Southern Study Area, 95 cm at the Young Jack Pine site in the Southern Study Area, 155 cm at the Old Jack Pine site at the Northern Study Area, and 55 cm at the Young Jack Pine site in the Northern Study Area. For measurements less than 20 cm in depth, the iterative procedure of Parkes and Siam (1979) was used to correct for neutron escape. Neutron probe measurements were typically made for transects of five tubes at the Old Jack Pine sites, and six tube transects at the Young Jack Pine sites with either approximately 5 or 10 meter spacing between access tubes.

To quantify the status of the soil water in the profile, in situ measurements for soil physical properties were conducted at each flux tower site using soil core samples and tension infiltrometer tests. The soil water retention function and the hydraulic conductivity function of the different soil textures in the project domain were determined. Tension infiltrometer tests were used for in situ determination of the saturated and the unsaturated soil hydraulic conductivity properties. Tension infiltrometer disks (Soil Measurement Systems) of 8 and 20 cm diameter were operated at three tensions to derive the saturated and near saturated (i.e. 0 to 20 cm tension) hydraulic conductivity values. The standard tension infiltrometer was modified to record the water level automatically at 10 second intervals using two pressure transducers and a datalogger. Each test was run at three target tensions of 3 cm, 6 cm, and 15 cm until steady-state infiltration rates were observed, and the actual field operating tensions were calculated using the pressure recorded at the bottom transducer. Multiple measurements at each site were made to characterize the spatial variability of soil hydraulic properties.

The saturated and residual volumetric water content were not directly measured in the field. These values were treated as fitting parameters when calculating the retention and the conductivity functions (Fuentes et al, 1992). Appropriate limits were placed on these parameters based on observed minimum and maximum water content values in the field using time domain reflectometry and the neutron probe. Because of entrapped air, impurities, and the existence of macropores in the soil samples, these values may not be the same as would be found from soil core analysis. Nevertheless, these values give the best fit to the limited set of retention data collected. These values were validated by comparing calculated parameters with soils of similar texture from the UNSODA database (USDA Salinity Lab). Although the measurements made are point, or spatially averaged measurements, the values reported are felt to be representative of areal averages for each flux tower site. Because they are based on in situ measurements, it is expected that the fitting parameters can be used effectively for modeling soil water processes at sites with similar soils and soil genesis as the flux tower sites.

Parameter estimates for the hydraulic conductivity and soil water retention functions were estimated from field infiltrometer tests and laboratory determined water retention from soil cores and presented in the following table. Saturated conductivity was determined by extrapolating the Gardner equation to zero tension using low tension data obtained with the tension infiltrometer. *N*, *alpha*, residual water content, and saturated water content were simultaneously fitted to both the infiltrometer and the core data using the van Genuchten equation for water retention and the van Genutchen-Mualem hydraulic conductivity function (Mualem constraint). Fitting criteria was the sum of the squared residuals of the natural log of the computed infiltrometer flow rates and the calculated flow rates, and the core volumetric water content versus the calculated volumetric water content (Mualem, 1976). Soil bulk densities were obtained from core data at the Southern Study Area and estimated for the Northern Study Areas. Soil bulk densities were not used in either the retention or conductivity functions and are provided for reference only. Only data from the A-horizon was used for tension infiltrometer tests. These parameters would most accurately represent the soil water properties of the top 15 cm of soil. Caution should be used when extrapolating these parameters to greater soil depths, yet it is expected that these parameters can be effectively used to model soil water properties at depths greater than 15 cm. This is because by most standards the soils at the BOREAS flux tower sites are relatively uniform along the vertical profile with little or no textural change. Soil bulk density values available in the BOREAS Information System (BORIS) can be used to evaluate changes which may affect the fitting parameters along the vertical profile.

Parameter Estimates for Hydraulic Conductivity and Soil Water Retention Functions

Property	NOJP	NYJP	SOJP	SYJP
Texture	Sand	Sand	Sand	Sand
Ksat (cm/d)	77	191	146	186
N	1.35	1.48	1.56	1.38
h_g (cm)	11.5	10.5	12.8	14.5
Alpha (1/cm)	0.087	0.095	0.078	0.069
θ Residual (fraction)	0.01	0.03	0.03	0.03
θ Saturated (fraction)	0.21	0.30	0.40	0.32
Bulk Density(g/cm^3)	1.45	1.45	1.45	1.19

In many respects the measurements for soil water content and soil hydraulic properties conducted during BOREAS were developed from similar measurements made in previous experiments. These include the HAPEX-MOBILHY experiment conducted in France in 1986, FIFE conducted in Kansas in 1987, and HAPEX-SAHEL conducted in Niger in 1992 (André et al,. 1988; Goutorbe et al 1989). Soil water monitoring in agricultural fields by neutron probes in HAPEX-MOBILHY was used to quantify the state of soil moisture conditions and perform hydrologic balance calculations (Goutorbe et al, 1989; Cuenca and Noilhan, 1991). HAPEX-SAHEL included soil water content monitoring by neutron, capacitance and TDR probes, and soil water monitoring by tensiometer and evaluation of soil hydraulic properties by tension infiltrometers (Cuenca et al., 1997). Certain field measurements and data analysis techniques applied in BOREAS were based on experience from these earlier experiments.

AUTOMATED WATER BALANCE SIMULATION

Principles of Water Balance

The mean zero-flux plane method for estimating soil water content in a soil profile through time is based on the work of Richards et al. (1956) who coined the term "static zone" for the plane that separates the region in the soil where the hydraulic gradient is upwards from the region where the hydraulic gradient is downwards. This plane, across which no water is assumed to flow, separates that part of the soil profile where evaporation takes place from the region in which drainage occurs. Assuming little or no soil texture variation in the soil profile, the zero-flux plane varies with time as the soil dries in periods of drought and is rewetted by precipitation events (Cuenca, 1987). By determining the average zero-flux plane for a two day period, and combining this knowledge with soil water content data derived from neutron probe data collected at each tube site, the change in soil water content above and below the mean zero-flux plane for the period of interest can be estimated. The equations used to automate determination of the location of the mean zero-flux plane and the profile soil water content for both the Southern and Northern Study Areas of the BOREAS at the Old and Young Jack Pine sites are presented in this section. The method requires total hydraulic head data to determine the location of the zero-flux plane, as well as soil water content data to quantify the change in soil water content above and below the mean zero-flux plane.

Soil water dynamics within the soil profile are controlled by the gradient of the total potential, or total hydraulic head, which is the sum of the gravitational head due to position and the soil water potential caused by the tension of the soil particles on the soil water with which the particles are in contact.

The total head, H_t (cm), is defined by Equation [1] below,

$$H_t = h_z + h(\theta_z) \qquad [1]$$

where

h_z = gravitational head due to position (cm)

$h(\theta_z)$ = soil water potential as function of soil water content (cm)

The above equation assumes that the effect of the osmotic potential normally caused by salinity is negligible which is a valid first assumption for the boreal forest environment (Cuenca et al, 1995). The datum for gravitational head is set at the soil surface so that positions below the soil surface have a negative gravitational head value. The total hydraulic head profile calculated for each site is used to identify the position of the daily zero-flux plane by determining at what depth the slope goes to infinity.

The van Genuchten (1980) and the Maulem (1976) hydraulic conductivity functions, presented by Equations [2] and [3] below are as follows

$$\theta_v = \theta_r + (\theta_s - \theta_r) / (1 + (h / h_g)^n)^m \qquad [2]$$

where

θ_v = volumetric soil water content (cm^3/cm^3)

θ_r = residual volumetric water content (cm^3/cm^3)

θ_s = saturated volumetric water content (cm^3/cm^3)

h = soil water tension (cm)

h_g = characteristic length scale fitting parameter (cm)

m, n = fitting parameters (dimensionless)

and the condition for *m* as a function of *n* shown below is the Mualem constraint (Mualem, 1976). The hydraulic conductivity function applied by van Genuchten (1980) is based on the model of Mualem (1976) and given as,

$$K(S_e) = K_s S_e [1 - (1 - S_e^{(1/m)})^m]^2 \qquad [3]$$

where

$K(S_e)$ = hydraulic conductivity as function of effective saturation (cm/d)

K_s = saturated hydraulic conductivity (cm/d)

l = tortuosity (fitting parameter - dimensionless)

m = 1 - 1 / n

van Genuchten (1980) shows that the variable h_g in Equation [2] can be thought of as the inverse of the air entry pressure, α, in the Brooks and Corey equation (Brooks and Corey, 1964). The condition for m as a function of n in the hydraulic conductivity parameterization is the Mualem constraint (Mualem, 1976). Based on his analysis of soil samples, Mualem arrived at a value of 0.5 for the tortuosity term in the above equation. An average value for K_s was determined by extrapolating a fitted Gardner (1958) exponential function to zero tension using the low tensions from each sequence of tension infiltrometer tests. The parameters for the water retention and hydraulic conductivity were simultaneously fitted using a non-linear fitting routine. The variables optimized were sum of the squared difference between the natural log of the calculated and the measured steady-state infiltration rates for the hydraulic conductivity and the weighted volumetric water contents for the water retention function. The fitting parameters, n, h_g, θ_s and θ_r were subject to the following constraints: $0 < n < 1$, $1 < (1 / h_g) < 2$, $\theta_s <$ observed maximum soil moisture, and $\theta_r > 0.01$. The tension infiltrometer tests were run at low tensions between 0 and 20 cm and the soil core water retention data were developed at relatively high tensions, between 100 cm and 15,000 cm. Combining these two sets of data using a unifying soil physics theory provides information across the whole range of tensions from saturation at 0 cm tension to the permanent wilting point at approximately 15,000 cm tension.

By determining the mean zero-flux plane of each tube and the soil water content as a function of soil depth, the soil water content available above and below the mean zero-flux plane can be determined by applying the appropriate limits of integration on the relationship put forth by Arya et al. (1975). Equation [4] gives the change in the amount of soil water content above the mean zero-flux plane (MZFP),

$$\int_{Z_{MZFP}}^{0} (\theta_1(z) - \theta_2(z))dz \qquad [4]$$

The functions describing the soil water content with depth, z, are given as $\theta_1(z)$ and $\theta_2(z)$ for successive days. The change in the total soil water content of the soil profile is based on the relationship presented in Equation [5],

$$\int_{SampleDepth}^{0} (\theta_1(z) - \theta_2(z))dz \qquad [5]$$

The change in total soil water content for the period of interest is calculated by integrating from the full depth of the sample tube to ground level. Equation [6] represents the change in soil water content below the mean zero-flux plane and is used to evaluate the amount of soil moisture available for drainage from the soil for the period of interest.

$$\int_{SampleDepth}^{0} (\theta_1(z) - \theta_2(z))dz - \int_{Z_{MZFP}}^{0} (\theta_1(z) - \theta_2(z))dz \qquad [6]$$

The drainage in the soil for the period of interest is the difference in the total profile soil water content below the mean zero-flux plane (Gardner, 1958). The automated water balance procedure presented here calculates the integrals using a numerical integration technique on the interpolated values of soil water content versus depth in the soil profile.

The distribution of precipitation is automatically accounted for in the soil moisture reading by the neutron probe. Therefore no adjustment of the water balance was made to account for precipitation. The equations presented here use the soil water content distribution with depth and time along with the position of the zero-flux plane with time at each site to estimate the change in soil water above and below the mean zero-flux plane.

Simulation Model Development

The van Genuchten equations presented in Equations [2] and [3] were coded into the computer program HYDROSOL and served as input for the Automated Water Balance Procedure (van Genuchten, Leij, and Yates, 1991). Due to the variability and length of these pre-processed data files, only the Southern Study Area, Old Jack Pine, IFC 1 is presented in Table A. These processed data files tabulate the Study Area site, the Intensive Field Campaign number, the tube site number, the day of year, the depth measurements in centimeters, the total hydraulic head in centimeters, and the soil water content in percent. They are processed through a Main Program, tailored per site, to quantify the soil water content at each site. Once again, due to the variability and length of these programs, Table B presents only the Main Program associated with processing the Southern Study Area, Old Jack Pine, IFC 1.

The SSA OJP IFC1 Main Program first declares the dimensions of the variables and sets the static variables for the tolerance factor allowed in the determination of the second derivatives used by the cubic spline interpolation function. The variable declaration includes the depth of the sample tube, the in situ value of the saturated soil water content, the depth interval for evaluating the interpolation, minimization, and integration step intervals. The data records for the depth, x_i, and total hydraulic head, y_i, are read and linearly interpolated back to ground level. This linear association, coded with respect to the coefficients, is formulated as an equation of the following form.

$$y = a_0 + a_1 x_i \qquad [7]$$

To produce the cubic spline interpolation function, the total hydraulic head data are processed through a derivative and tridiagonal subroutine function to fill the associated array matrices. The general form of the coded derivative function is as follows (English, 1992; Press, 1986),

$$F_i' = \frac{F''_i(x_i)}{6\Delta x_i}(-3\Delta x_i^2 + \Delta x_i^2) + \frac{F''_i(x_i+1)}{6\Delta x_i}(-\Delta x^2) + (\frac{f_{i+1} - f_i}{\Delta x_i}) \quad [8]$$

The total hydraulic head data, derived from Equation [1], is processed through the Total Hydraulic Head and Soil Water Content Data Interpolation Function, presented in Table C, to determine the daily zero-flux plane (Press, 1986). This function is a piece-wise interpolation routine that allows for different polynomials to connect adjacent points with a third degree polynomial, and takes the form

$$F_i(x) = a_0 + a_1 x + a_2 x^2 + a_3 x^3 \quad [9]$$

where $\{a_0, a_1, a_2, a_3\}$ differ between interpolated values.

The function finds the value of the variable that yields the minimum of the function by zooming in on the minimum instead of reducing the interval that holds the minimum value. The method uses two guesses for the minimum as well as estimates for the slope at these points to perform the interpolation. The correct determination of the zero-flux plane is essential in the calculation of the soil water content available above and below the mean zero-flux plane as this value varies considerably with depth and time. By checking a short table of known values and curve fitting to find the other values, the cubic spline interpolation method presents a function to match the set of experimental total hydraulic head values such that the function at any point of interest presents a reasonable value. The extrapolated interval provides a smooth function that exactly matches the given values. In this approach, the equality of each successive function at the end-points is fixed, and the first derivatives of successive equations are set equal at the shared points. The second derivatives of the total hydraulic head data, rewritten as a Lagrangian interpolation polynomial, take on the form of the linear function

$$F_i''(x) = 2a_2 + 6a_3 x \qquad [10]$$

These are set equal at the shared points, and set equal to zero at the end points. Rewritten as a Lagrangian interpolation polynomial,

$$F_i''(x) = F_i''(x_i)\left(\frac{x - x_{i+1}}{x_i - x_{i+1}}\right) + F_i''(x_{i+1})\left(\frac{x - x_i}{x_{i+1} - x_i}\right) \qquad [11]$$

where we define, $\Delta x_i = x_{i+1} - x_i$, so that

$$F_i''(x) = F_i''(x_i)\left(\frac{x_{i+1} - x}{\Delta x_i}\right) + F_i''(x_{i+1})\left(\frac{x - x_i}{\Delta x_i}\right) \qquad [12]$$

Integrating twice, we obtain

$$F_I(x) = \frac{F_i''(x_i)}{6\Delta x_i}(x_{i+1} - x)^3 + \frac{F_i''(x_{i+1})}{6\Delta x_i}(x - x_i)^3 + Ax + B \qquad [13]$$

Now, for each interval there are four unknowns $F_I''(x_i)$, $F_I''(x_{i+1})$, A, and B. Solving for A, and B by evaluating the equations for each interval at the end points,

$$F_I\ (x_i) = f_i \qquad [14]$$

$$F_I(x_{i+1}) = f_{i+1} \qquad [15]$$

Evaluating x_i at each successive interval we have

$$F_I(x_i) = \frac{F_i''(x_i)}{6\Delta x_i}(x_{i+1} - x_i)^3 + \frac{F_i''(x_{i+1})}{6\Delta x_i}(x - x_i)^3 + Ax + B \qquad [16]$$

$$F_I = \frac{F_i''(x_i)}{6}(\Delta x_i)^2 + Ax_i + B \qquad [17]$$

Evaluating at x_{i+1}

$$F_{I+1} = \frac{F_i''(x_{i+1})}{6}(\Delta x_i)^2 + Ax_{i+1} + B \qquad [18]$$

Subtracting equation [16] from equation [15] and solving for A,

$$A = \left(\frac{f_{i+1} - f_i}{\Delta x_i} \right) - \left(F_i''(x_{i+1}) - F_i''(x_i) \right) \frac{\Delta x_i}{6} \qquad [19]$$

solving for B by substitution,

$$B = \left(\frac{f_i x_{i+1} - f_{i+1} x_i}{\Delta x_i} \right) + \left(F_i''(x_{i+1}) x_i - F_i''(x_i)(x_{i+1}) \right) * \frac{\Delta x_i}{6} \qquad [20]$$

Substituting into equation [12],

$$\begin{aligned} F_i(x) = {} & \frac{F_i''(x_i)}{6\Delta x_i} \{ (x_{i+1} - x)^3 + x(\Delta x_i)^2 - x_{i+1}(\Delta x_i)^2 \} + \\ & \frac{F_i''(x_{i+1})}{6\Delta x_i} \{ (x - x_i)^3 + x_i(\Delta x_i)^2 - x(\Delta x_i)^2 \} + \\ & f\left(\frac{x_{i+1} - x}{\Delta x_i} \right) + f_{i+1}\left(\frac{x - x_i}{\Delta x_i} \right) \end{aligned} \qquad [21]$$

For each interval we have one equation with two unknowns, A, and B for a total of 2n terms to be derived. Using the first derivatives, presented in equation [13], the general form of the total hydraulic head data takes the form

$$\begin{aligned} F_i'(x) = {} & \frac{F_i''(x_i)}{6\Delta x_i} \{ -3(x_{i+1} - x)^2 + (\Delta x_i)^2 \} + \\ & \frac{F_i''(x_{i+1})}{6\Delta x_i} \{ 3(x - x_i)^2 - (\Delta x_i)^2 \} + \left(\frac{f_{i+1} - f_i}{\Delta x_i} \right) \end{aligned} \qquad [22]$$

Evaluating $F_i'(x)$ at x_i

$$F_i'(x_i) = \frac{F_i''(x_i)}{6\Delta x_i}\{-3(\Delta x_i)^2 - (\Delta x_i)^2\} + \frac{F_i''(x_{i+1})}{6\Delta x_i}\{-(\Delta x_i)^2\} + \left(\frac{f_{i+1} - f_i}{\Delta x_i}\right) \quad [23]$$

Evaluating $F_{i-1}'(x)$ at x_i, so that the fixed terms x_i and x_{i+1} become x_{i-1} and x_i,

$$F_{i-1}'(x_i) = \frac{F_{i-1}''(x_{i-1})}{6\Delta x_{i-1}}(\Delta x_{i-1})^2 + \frac{F_{i-1}''(x_{i-1})}{6\Delta x_{i-1}}(2\Delta x_{i-1})^2 + \left(\frac{f_i - f_{i-1}}{\Delta x_i}\right) \quad [24]$$

Setting the two equations equal to each other and rearranging,

$$\frac{\Delta x_{i-1}}{\Delta x}\{F_{i-1}'(x_{i-1}) + 2F_{i-1}''(x_i) + 2F_i''(x_i) + F_i''(x_{i+1})\} = 6\left(\frac{f_{i+1} - f_{i-1}}{\Delta x_i^2} - \frac{f_i - f_{i-1}}{\Delta x_i \Delta x_{i-1}}\right) \quad [25]$$

Combining the two derivatives for n-1 additional equations and assuming the second derivatives of successive equations are equal at the shared points,

$$\frac{\Delta x_{i-1}}{\Delta x}\{g''(x_{i-1}) + 4g''(x_i) + g''(x_i)\} = 6\left(\frac{f_{i+1} - f_{i-1}}{\Delta x_i^2} - \frac{f_i - f_{i-1}}{\Delta x_i \Delta x_{i-1}}\right) \quad [26]$$

For evenly spaced data, the general form of the equation then becomes,

$$g''(x_{i-1}) + 4g''(x_i) + g''(x_i)\} = 6\left(\frac{f_{i+1} - 2f +_i f_{i-1}}{\Delta x_i^2}\right) \quad [27]$$

The algorithm, presented in Table E, uses Equation [27] in the interpolation algorithm to obtain the intermediate values (Press, 1986). This system of equations is a simple tridiagonal matrix form that is solved with a degenerate version of the Gaussian elimination method, where

$$x_i = \frac{f_i - \sum_{k=i}^{i-1} g_{jk} x_k}{g_{jj}} \qquad [28]$$

The code for the Tridiagonal Matrix Private Function call is presented in Table D (Press, 1986). The mean zero-flux plane per two day count is evaluated as the average of two successive day values of the zero-flux plane. The array for the second derivative of the soil water content is evaluated followed by a cubic spline interpolation function call to keep a table of the observed soil water content values and to return a matrix of interpolated values at intervals set by the DepthStep variable.

The change in soil water content above the mean zero-flux plane, presented in Equation [4], is evaluated by calling the Change In Soil Moisture Integration Function subroutine and integrating the array of interpolated soil water content values from the mean zero-flux plane to ground level at depth zero. The code is an iterative method to calculate the area by successive refinements and is presented in Table F (Press, 1986). Following Equation [5], the cubic spline interpolation matrix of the total soil moisture is integrated over the full length of the tube to determine the total soil water content at the site. The function subroutine Change In Soil Moisture is once again called to evaluate the total soil water content at the site by integrating from ground level through the full depth of the sample tube. The soil water content available for drainage at the tube site, from Equation [6], is evaluated as the change in total soil water content below the mean zero-flux plane.

RESULTS

SSA OJP IFC 1

Measurements were made in five neutron probe access tubes during 1994 on days of year 145 through 167. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 1. In the first tube on days of year 148, 157 and 165 the change in soil moisture above the MZFP increased by 3.4, 0.7, and 7.4 mm following rainfall events of 8, 4.4, and 11 mm. In the absence of rainfall on days of year 151 through 153 and 159 through 163, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.7 mm on day of year 150.

In the second tube on days of year 148, 157 and 165 the change in soil moisture above the MZFP increased by 1.6, 1.3, and 5.4 mm following rainfall events of 9, 4.8 and 10 mm. In the absence of rainfall on days of year 151 through 153 and 159 through 163, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 1.5 mm on day of year 161. In the third tube on days of year 148, 157, and 165 the change in soil moisture above the MZFP increased by 5.3, 1.8, and 11.7 mm following rainfall events of 11, 7, and 22 mm. In the absence of rainfall on days of year 151 through 153 and 159 through 163, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 4.8 mm on day of year 167.

In the fourth tube on days of year 148, 157, and 165 the change in soil moisture above the MZFP increased by 5.6, 2.1, and 9.9 mm following rainfall events of 10, 6,

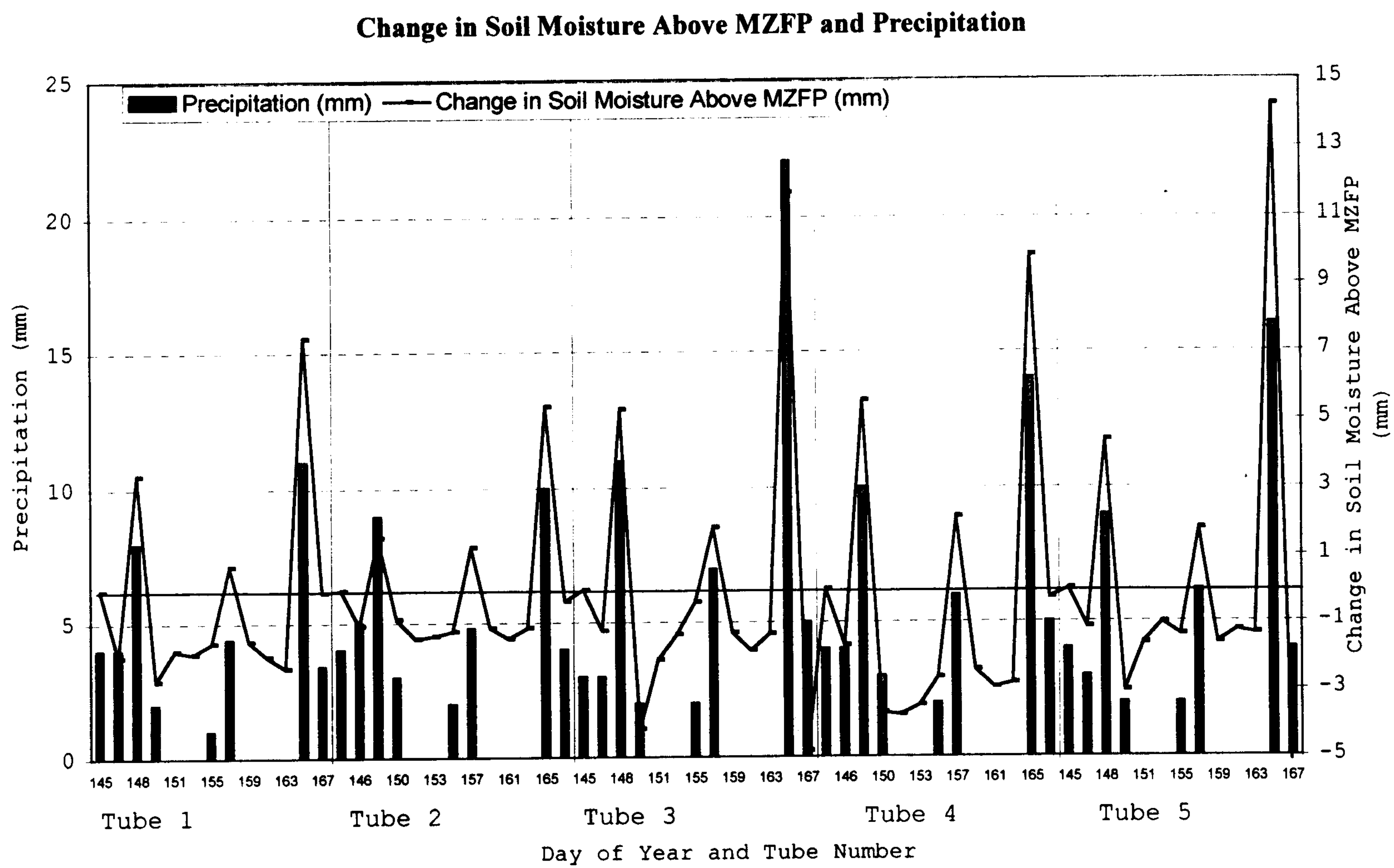

Figure 1. SSA OJP IFC 1 Change in Soil Moisture Above MZFP and Precipitation

and 14 mm. In the absence of rainfall on days of year 151 through 153 and 159 through 163, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.8 mm on day of year 151. In the fifth tube on days of year 148, 157, and 165 the change in soil moisture above the MZFP increased by 4.4, 1.8, and 14.2 mm following rainfall events of 9, 6.2, and 16 mm. In the absence of rainfall on days of year 151 through 153 and 159 through 163, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 6.3 mm on day of year 167.

The change in the MZFP versus precipitation is pictured in Figure 2. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 34.9 cm on day of year 163. After the largest rainfall of 11 mm on day of year 165, the MZFP was brought to its minimum value of 5.2 cm.

In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 29.6 cm on day of year 155. After the largest rainfall of 10 mm on day of year 165 the MZFP was brought to its minimum value of 9.55 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 24.8 cm on day of year 167. After the largest rainfall of 11 mm on day of year 148 followed by 2 mm on day of year 150, the MZFP was brought to its minimum value of 14.8 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 45 cm on days of year 155 and 163. After the largest rainfall of 14 mm on day of year 165 followed by 5 mm on day of year 167, the MZFP was brought to its

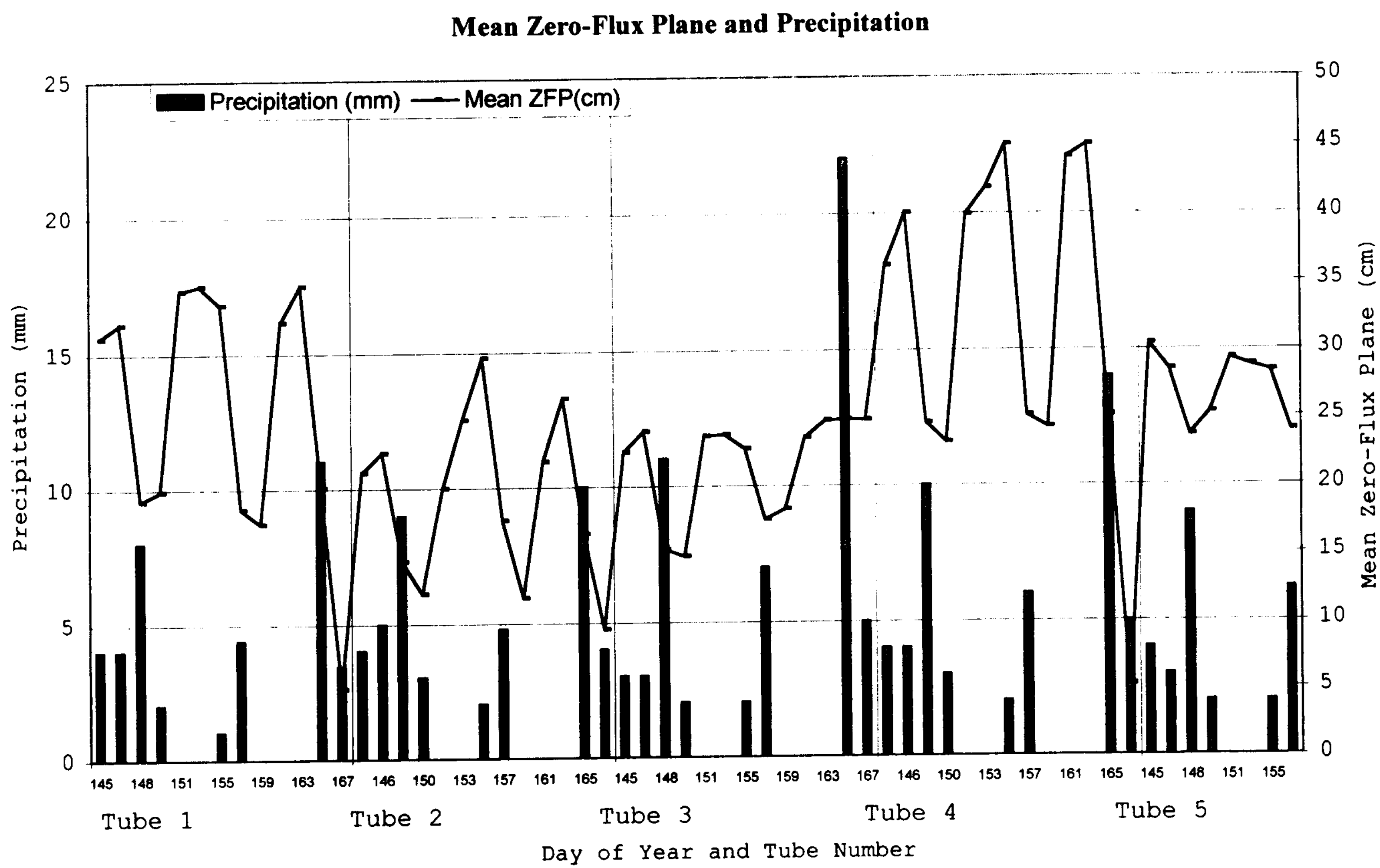

Figure 2. SSA OJP IFC 1 Mean Zero-Flux Plane and Precipitation

minimum value of 5.2 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 29.3 cm on day of year 151. The MZFP was brought to its minimum value of 23.3 cm after a rainfall of 6.2 mm on day of year 157.

SSA OJP IFC 2

Measurements were made in five neutron probe access tubes during 1994 on days of year 202 through 231. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 3. In the first4 tube on days of year 224 and 231 the change in soil moisture above the MZFP increased by 0.2 and 1.6 mm following rainfall events of 3 and 4 mm. In the absence of rainfall on days of year 202 through 208 and 212 through 216 the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.6 mm on day of year 204.

In the second tube on days of year 210, 224 and 231, the change in soil moisture above the MZFP increased by 0.4, 0.5, and 0.4 mm following rainfall events of 4, 0 and 4 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221 the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.0 mm on day of year 204. In the third tube on days of year 210 and 224, the change in soil moisture above the MZFP increased by 0.3 and 0.3 mm following rainfall events of 2 and 2 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221 the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.9 mm on day of year 221.

In the fourth tube on days of year 210, 224 and 231 the change in soil moisture above the MZFP increased by 0.8, 1.1 and 0.7 mm following rainfall events of 5, 4 and 4 mm. In the absence of rainfall on days of year 212 through 216 the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.1 mm on day of year 212. In the fifth tube the change

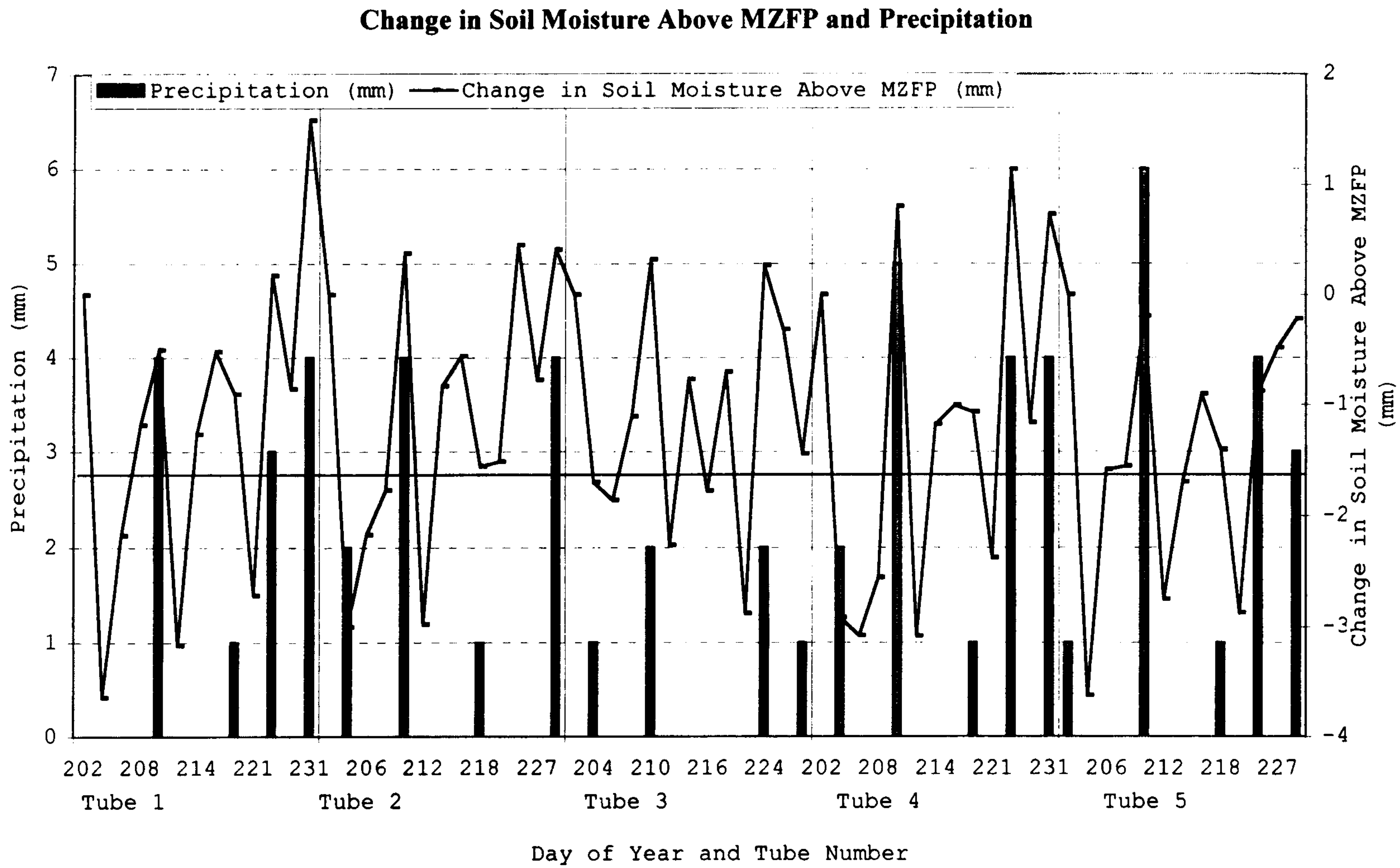

Figure 3. SSA OJP IFC 2 Change in Soil Moisture Above MZFP and Precipitation

in soil moisture above the change in the MZFP barely increased following a rainfall event of 6mm on day of year 210. In the absence of rainfall on days of year 204 through 208 and 212 through 216 the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.6 mm on day of year 204.

The change in the MZFP versus precipitation is pictured in Figure 4. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 202 through 208 and 212 through 216 reaching a maximum of 40 cm on day of year 231. After a rainfall of 4 mm on day of year 210 followed by another rainfall event of 4 mm on day of year 231, the MZFP was brought to a minimum value of 39.9 cm.

In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 212 through 216 and 221 through 227 reaching a maximum of 40 cm on days of year 224 through 231. After the largest rainfall of 4 mm on days of year 210 and 231, the MZFP was brought to a minimum value of 40 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 206 through 208 and 212 through 221 reaching a maximum of 38.7 cm on day of year 224. After the largest rainfall of 2 mm on days of year 210 and 224, the MZFP was brought to a minimum value of 38.6 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 206 through 208 and 212 through 216 reaching a maximum of 40 cm on days of year 216 through 231. After the largest rainfall of 5 mm on day of year 210 the MZFP was brought to a minimum value of 38.3 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on

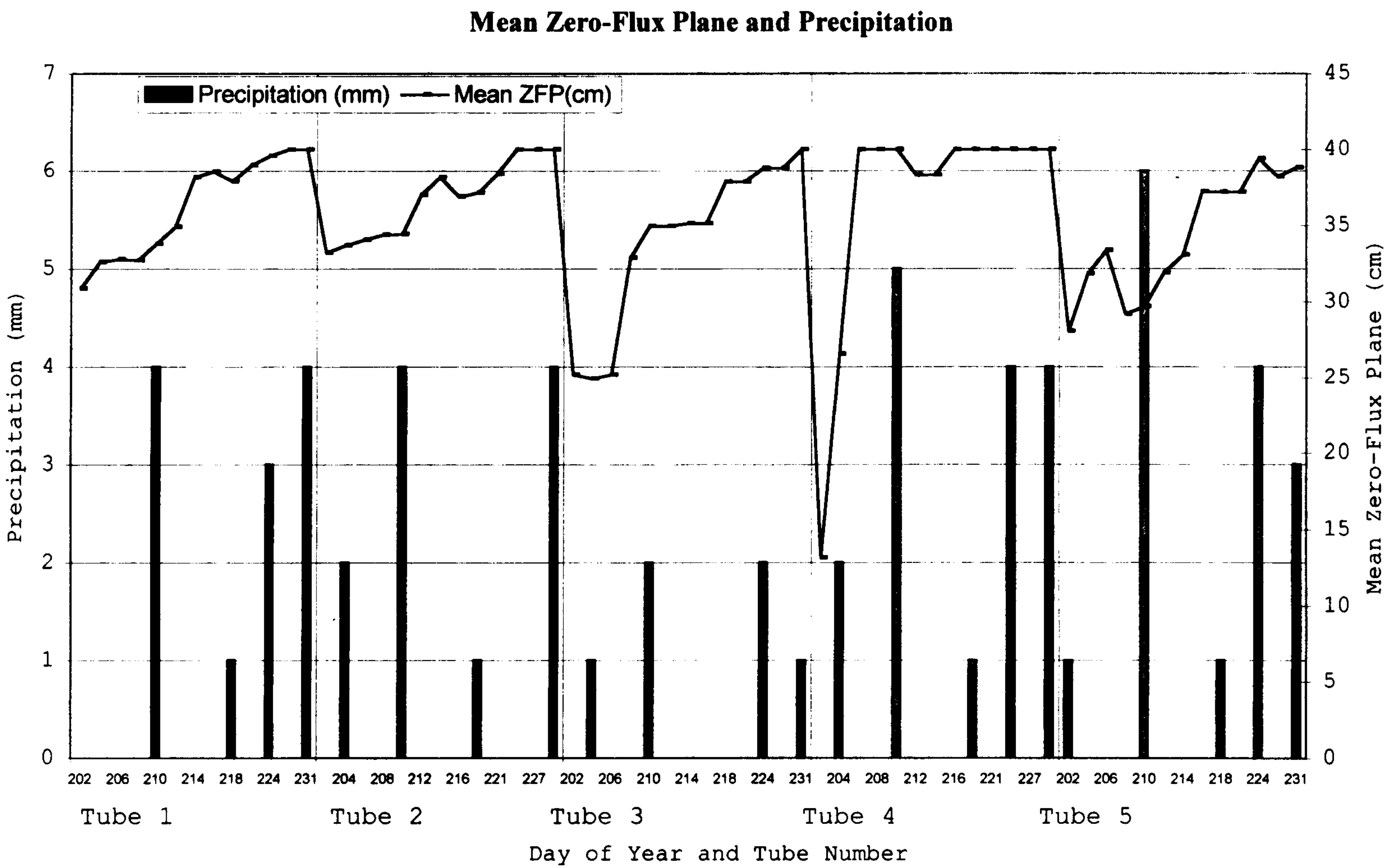

Figure 4. SSA OJP IFC 2 Mean Zero-Flux Plane and Precipitation

days of year 212 through 216 reaching a maximum of 37.3 cm on day of year 216. The MZFP was brought to its minimum value of 29.7 cm after a rainfall of 6 mm on day of year 210.

SSA OJP IFC 3

Measurements were made in five neutron probe access tubes during 1994 on days of year 242 through 261. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 5. In the first tube on day of year 249 the change in soil moisture above the MZFP increased by 3.1 mm following a rainfall event of 12 mm. In the absence of rainfall on days of year 242 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 0.6 mm on day of year 256.

In the second tube on days of year 249 the change in soil moisture above the MZFP increased by 5.2 mm following a rainfall event of 20 mm. In the absence of rainfall on days of year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 1.3 mm on day of year 251. In the third tube on days of year 249 the change in soil moisture above the MZFP increased by 7.8 mm following a rainfall event of 13 mm. In the absence of rainfall on days of year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 1.2 mm on day of year 251.

In the fourth tube on days of year 249 the change in soil moisture above the MZFP increased by 7.2 mm following a rainfall event of 15 mm. In the absence of rainfall on days of year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 1.8 mm on day of year 251. In the fifth tube on days of year 249 the change in soil moisture above the MZFP increased by 5.1 mm following a rainfall event of 12 mm. In the absence of rainfall on days of year 244 through 246 and

Change in Soil Moisture Above MZFP and Precipitation

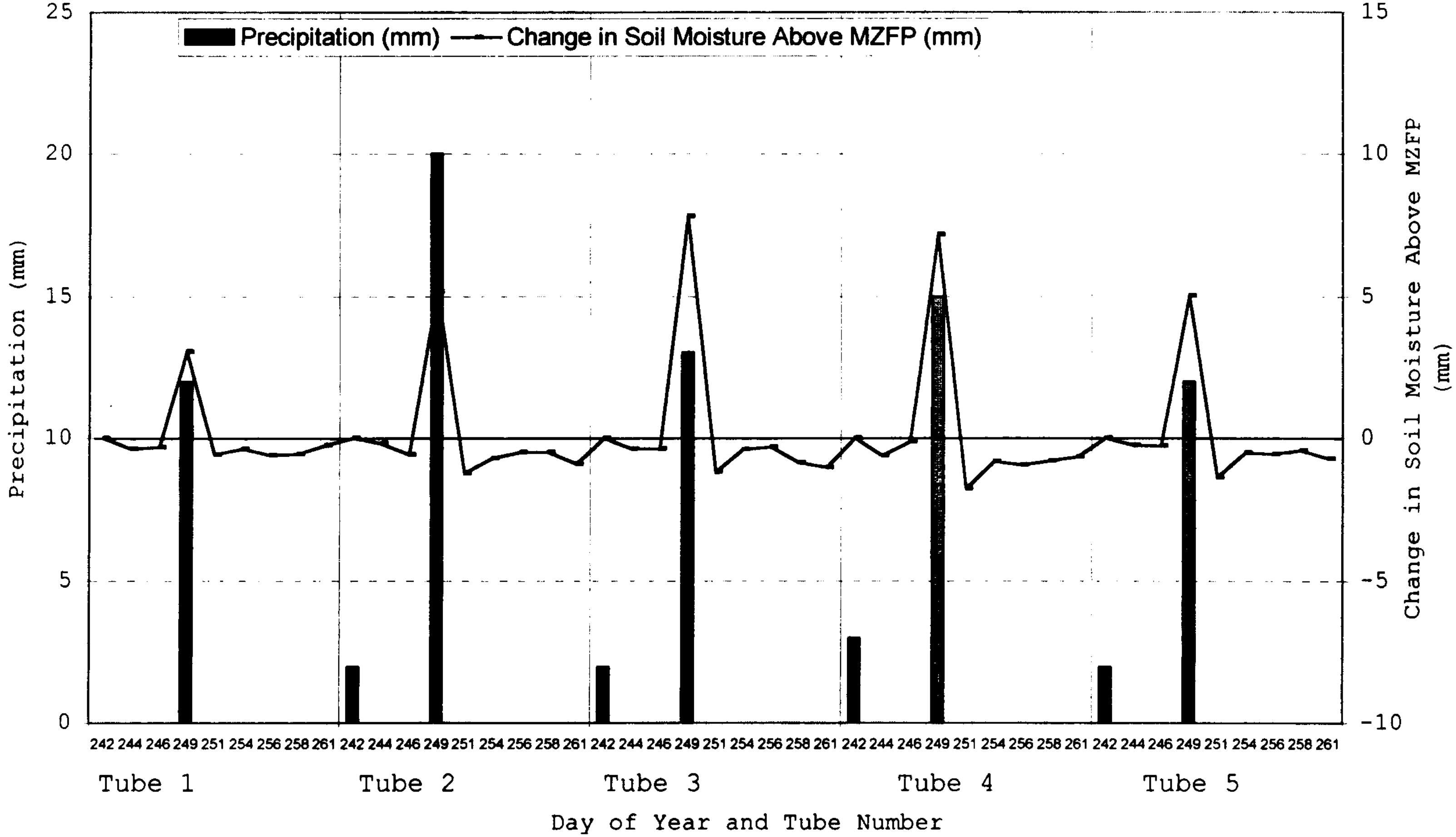

Figure 5. SSA OJP IFC 3 Change in Soil Moisture Above MZFP and Precipitation

251 through 261, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 1.4 mm on day of year 251.

The change in the MZFP versus precipitation is pictured in Figure 6. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 242 through 246 and 251 through 261 reaching a maximum of 28.7 cm on day of year 244. After the largest rainfall of 12 mm on day of year 249, the MZFP was brought to its minimum value of 15.2 cm.

In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 28.8 cm on day of year 261. After the largest rainfall of 20 mm on day of year 249 the MZFP remained at a minimum value of 28.8 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 37.1 cm on day of year 251. After the largest rainfall of 13 mm on day of year 249, the MZFP was brought to its minimum value of 14.8 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 29.1 cm on days of year 249 through 251. After the largest rainfall of 15 mm on day of year 249, the MZFP was brought to its minimum value of 28.6 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 28.9 cm on day of year 258. The MZFP was brought to its minimum value of 45 cm after a rainfall of 12 mm on day of year 249.

Mean Zero-Flux Plane and Precipitation

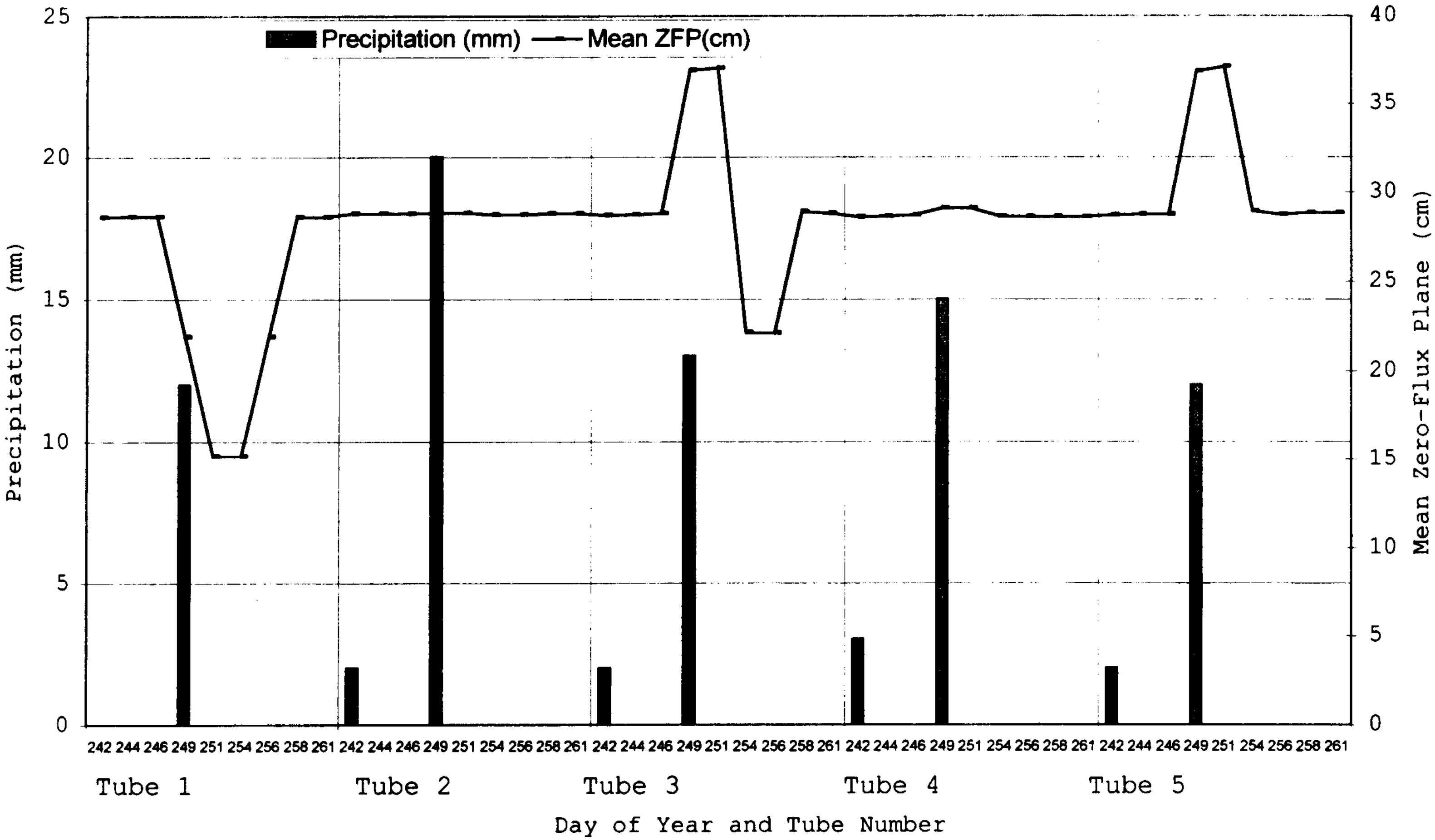

Figure 6. SSA OJP IFC 3 Mean Zero-Flux Plane and Precipitation

SSA YJP IFC 2

Measurements were made in five neutron probe access tubes during 1994 on days of year 202 through 231. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 7. In the first tube on day of year 231 the change in soil moisture above the MZFP increased by 0.4 mm following a rainfall event of 2 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 4.0 mm on day of year 208.

In the second tube on days of year 210 and 231 the change in soil moisture above the MZFP increased by 0.6 and 0.4 mm following rainfall events 8 and 4 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 4.6 mm on day of year 206. In the third tube on days of year 210, 224, and 231 the change in soil moisture above the MZFP increased by 1.0, 0.2, and 0.3 mm following rainfall events of 6, 3, and 2 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.7 mm on day of year 204.

In the fourth tube on days of year 210, 224, and 231 the change in soil moisture above the MZFP increased by 4.4, 1.6, and 1.7 mm following rainfall events of 8, 5, and 4 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 4.5 mm on day of year 206. In the fifth tube on days of year 224 and 231 the change in soil moisture above the MZFP

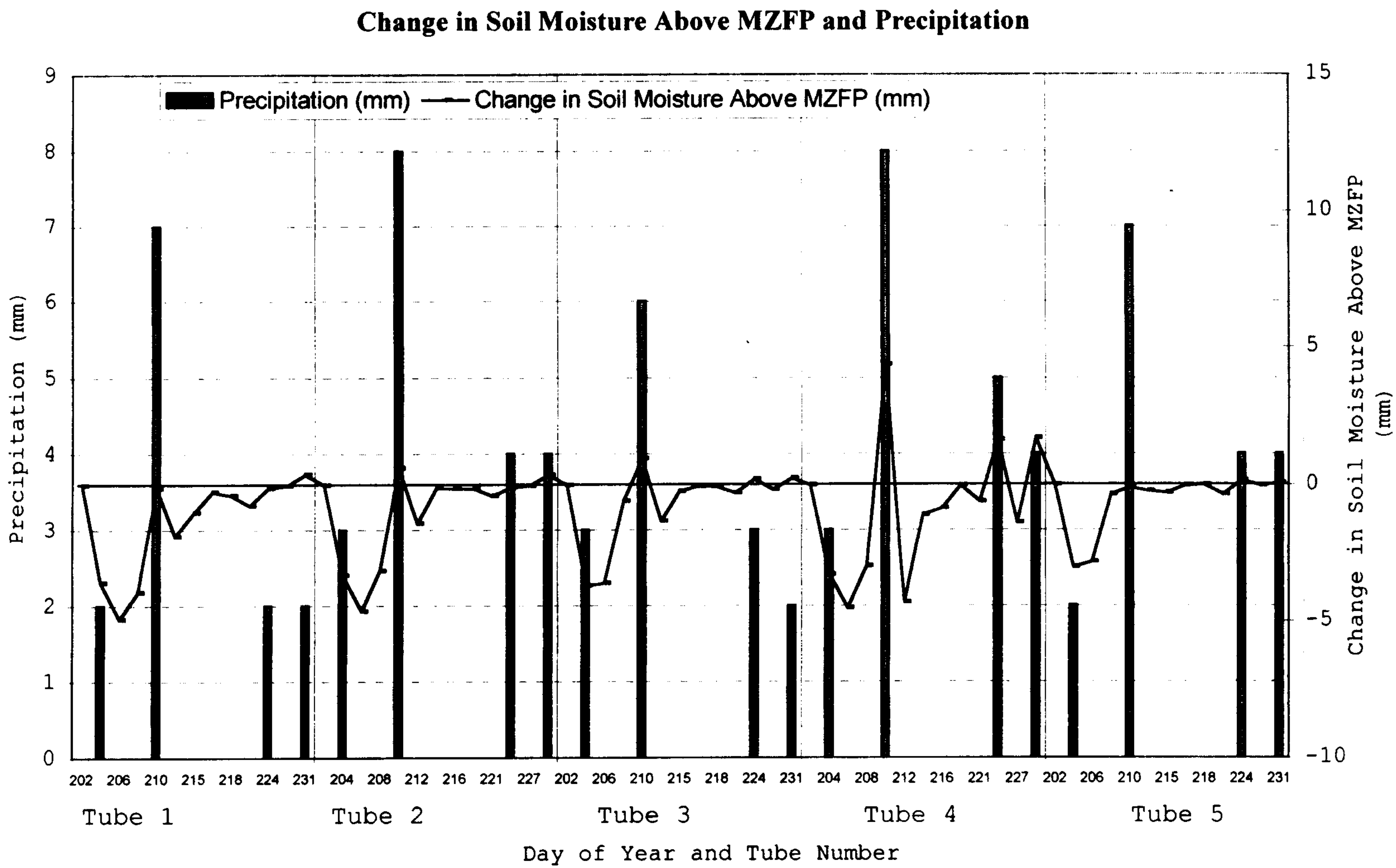

Figure 7. SSA YJP IFC 2 Change in Soil Moisture Above MZFP and Precipitation

increased by 0.2 and 0.1 mm following rainfall events of 4 and 4 mm. In the absence of rainfall on days of year 206 through 208 and 212 through 221, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.0 mm on day of year 204.

The change in the MZFP versus precipitation is pictured in Figure 8. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 206 through 208 reaching a maximum of 40 cm on day of year 204. After the largest rainfall of 7 mm on day of year 210, the MZFP was brought to its minimum value of 15.1 cm.

In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 202 through 204 reaching a maximum of 40 cm on day of year 204. After the largest rainfall of 8 mm on day of year 210 the MZFP was brought to its minimum value of 5.2 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 24.8 cm on day of year 167. After the largest rainfall of 11 mm on day of year 148 followed by 2 mm on day of year 150, the MZFP was brought to its minimum value of 14.8 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159 through 163 reaching a maximum of 45 cm on days of year 155 and 163. After the largest rainfall of 14 mm on day of year 165 followed by 5 mm on day of year 167, the MZFP was brought to its minimum value of 5.2 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 151 through 153 and 159

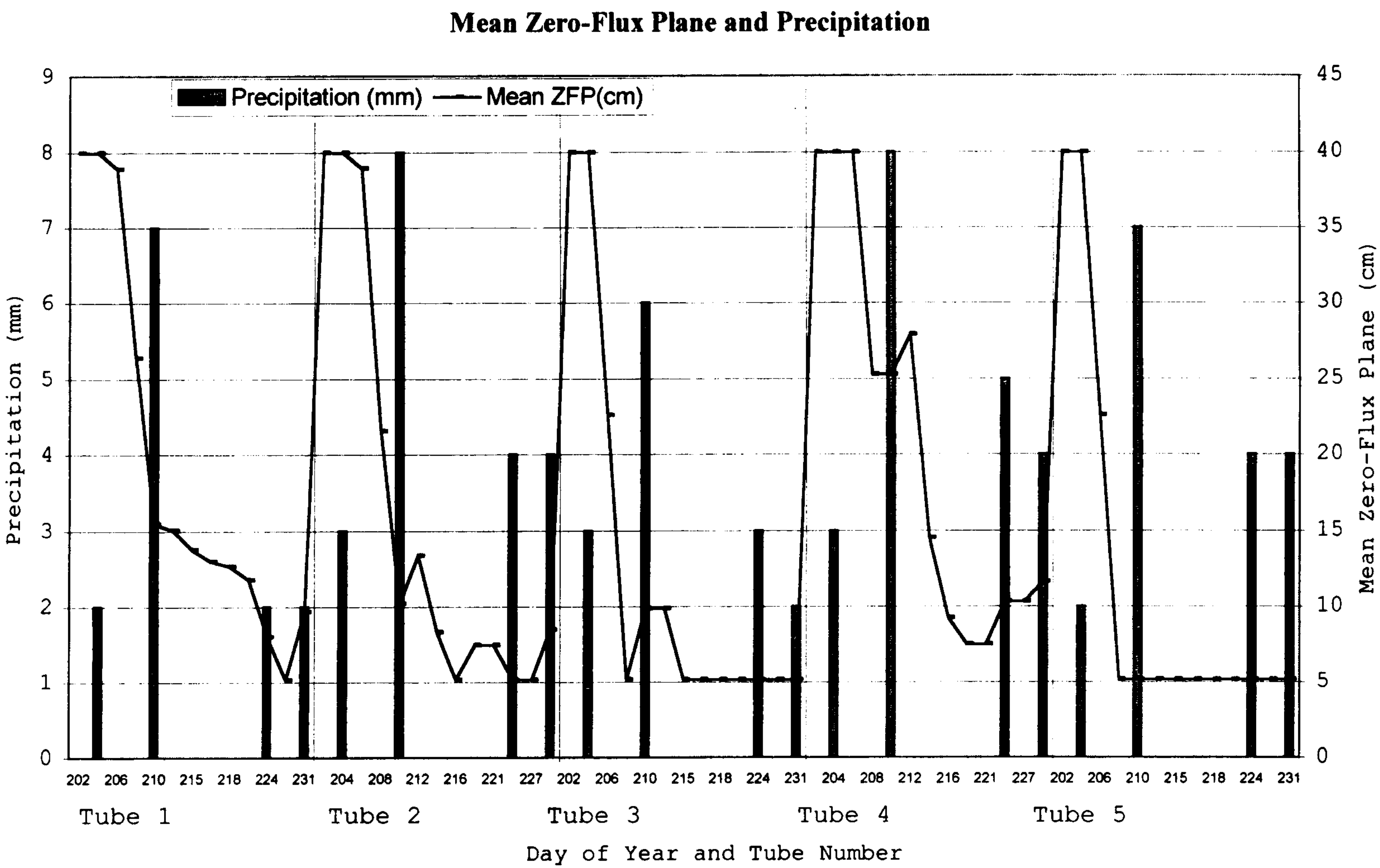

Figure 8. SSA YJP IFC 2 Mean Zero-Flux Plane and Precipitation

through 163 reaching a maximum of 29.3 cm on day of year 151. The MZFP was brought to its minimum value of 23.3 cm after a rainfall of 6.2 mm on day of year 157.

SSA YJP IFC 3

Measurements were made in six neutron probe access tubes during 1994 on days of year 242 through 261. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 9. In the first tube on days of year 246 and 249 the change in soil moisture above the MZFP increased by 0.2 and 8.0 mm following rainfall events of 1 mm on day of year 242 and 13 mm on day of year 249. In the absence of rainfall on days of year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.2 mm on day of year 251.

In the second tube on days of year 246, 249, and 258 the change in soil moisture above the MZFP increased by 0.1, 0.5, and 0.1 mm following rainfall events of 3 mm on day of year 242 and 18 mm on day of year 249. In the absence of rainfall on days of year 151 through year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 0.4 mm on day of year 251. In the third tube on days of year 246 and 249 the change in soil moisture above the MZFP increased by 0.1 and 7.0 mm following rainfall events of 1 mm on day of year 242 and 11 mm on day of year 249. In the absence of rainfall on days of year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.0 mm on day of year 251.

In the fourth tube on days of year 249 the change in soil moisture above the MZFP increased by 12.7 mm following rainfall events of 2 mm on day of year 242 and 19 mm on day of year 249. In the absence of rainfall on days of year 244 through 246 and 251 through 261, the amount of soil moisture above the MZFP decreased

Change in Soil Moisture Above MZFP and Precipitation

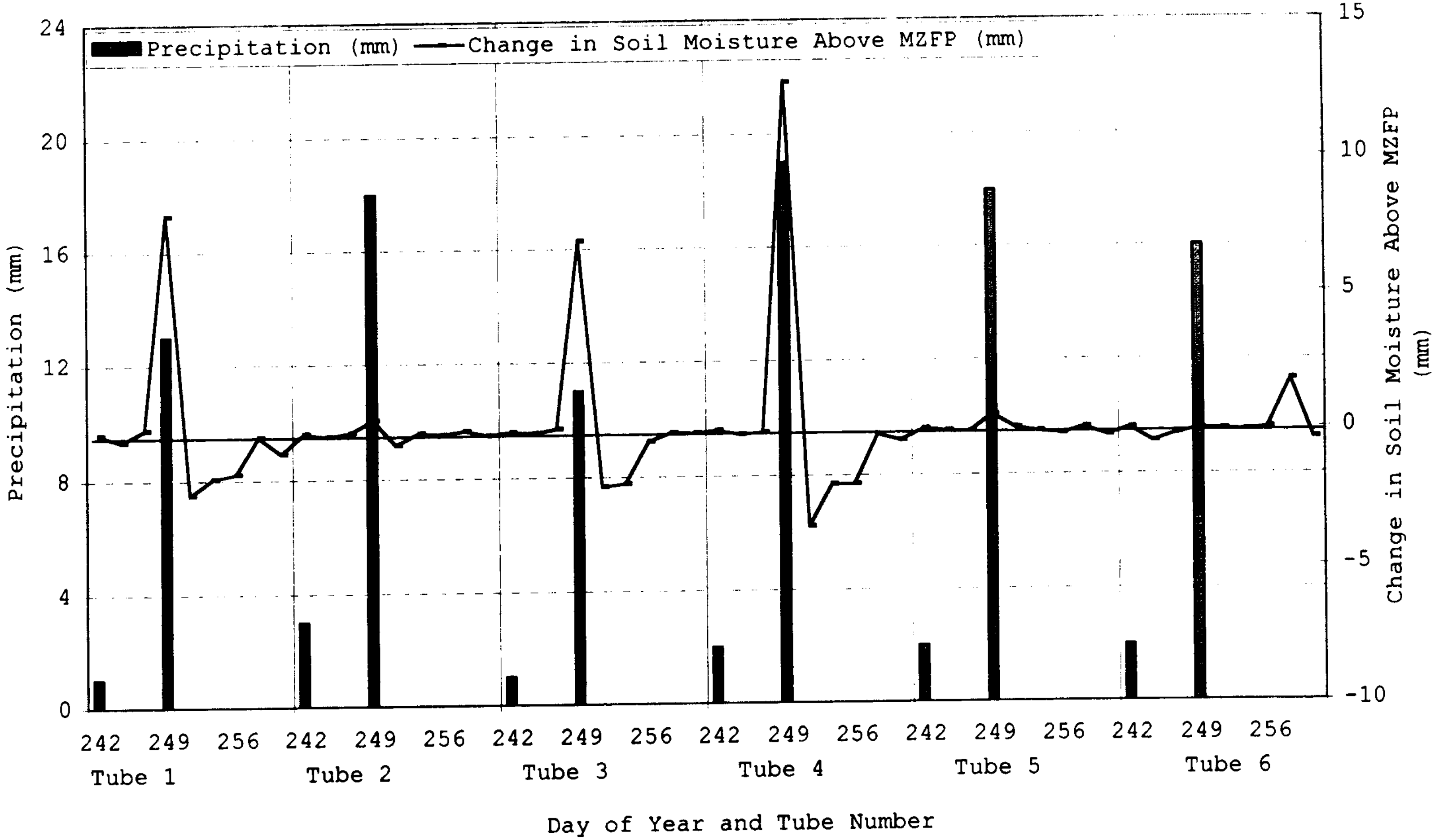

Figure 9. SSA YJP IFC 3 Change in Soil Moisture Above MZFP and Precipitation

indicating the use of soil moisture for evapotranspiration peaking at 3.5 mm on day of year 251.

In the fifth tube on days of year 249, 251 and 258 the change in soil moisture above the MZFP increased by 0.5, 0.1, and 0.1 mm following rainfall events of 2 mm on day of year 242 and 18 mm on day of year 249. In the absence of rainfall on days of year 244 through 246 and 251 through 261, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 0.3 mm on day of year 261. In the sixth tube on day of year 258 the change in soil moisture above the MZFP increased by 1.7 mm following rainfall events of 2 mm on day of year 242 and 16 mm on day of year 249. In the absence of rainfall on days of year 244 through 246 and 251 through 261, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 0.5 mm on day of year 244.

The change in the MZFP versus precipitation is pictured in Figure 10. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 34.9 cm on day of year 163. After the largest rainfall of 11 mm on day of year 165, the MZFP was brought to its minimum value of 5.2 cm. In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 29.6 cm on day of year 155. After the largest rainfall of 10 mm on day of year 165 the MZFP was brought to its minimum value of 9.55 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 24.8 cm on day of year 167. After the largest

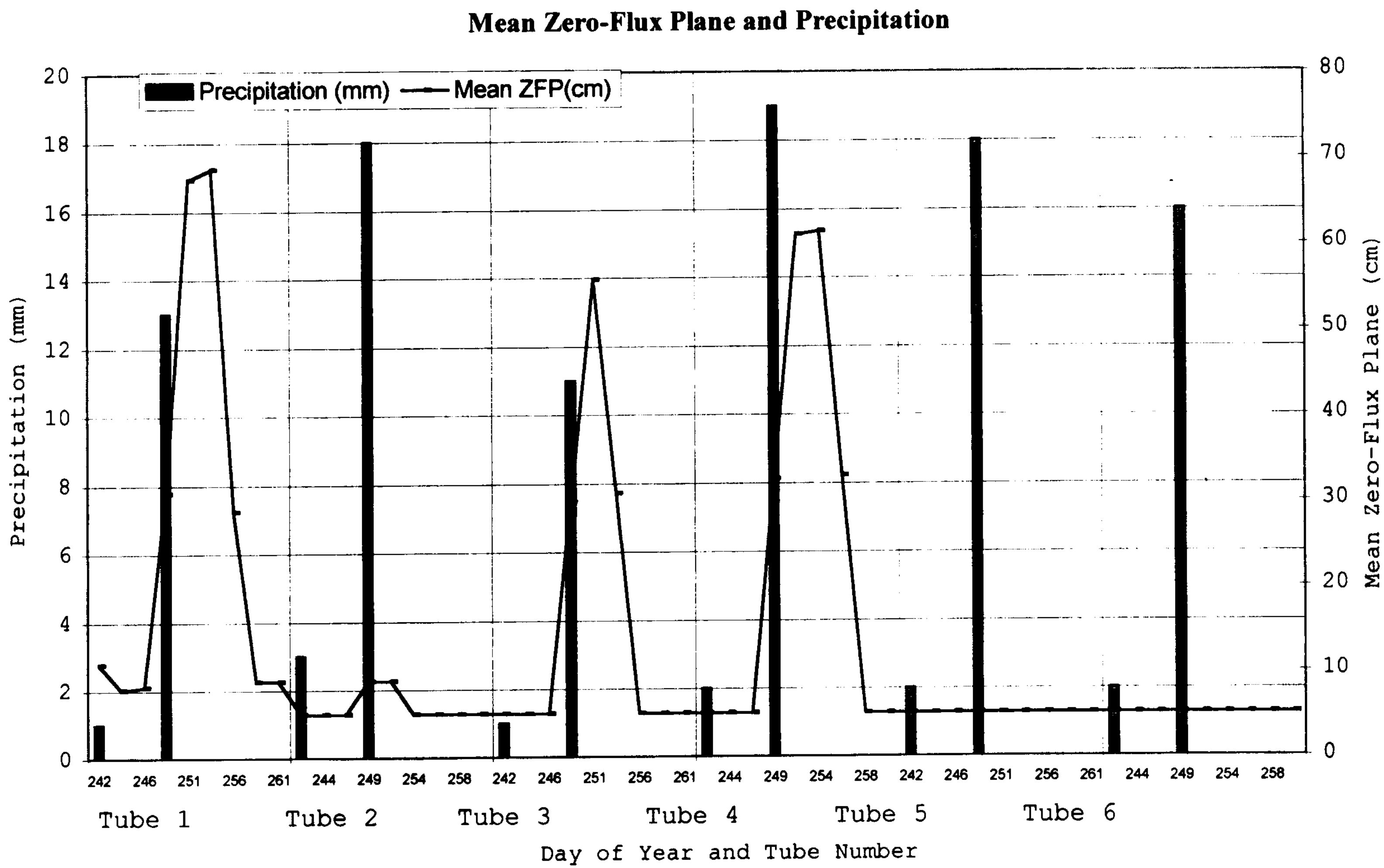

Figure 10. SSA YJP IFC 3 Mean Zero-Flux Plane and Precipitation

rainfall of 11 mm on day of year 148 followed by 2 mm on day of year 150, the MZFP was brought to its minimum value of 14.8 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 45 cm on days of year 155 and 163. After the largest rainfall of 14 mm on day of year 165 followed by 5 mm on day of year 167, the MZFP was brought to its minimum value of 5.2 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 244 through 246 and 251 through 261 reaching a maximum of 29.3 cm on day of year 151. The MZFP was brought to its minimum value of 23.3 cm after a rainfall of 6.2 mm on day of year 157.

NSA OJP IFC 1

Measurements were made in five neutron probe access tubes during 1994 on days of year 150 through 166. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 11. In the first tube on days of year 154 and 166 the change in soil moisture above the MZFP increased by 0.1 and 12.2 mm following a rainfall event of 48 mm on day of year 166. In the absence of rainfall on days of year 150 through 164, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.6 mm on day of year 156.

In the second tube on days of year 152, 162 and 166 the change in soil moisture above the MZFP increased by 0.6, 0.4, and 17.7 mm following a rainfall event of 22 mm on day of year 166. In the absence of rainfall on days of year 150 through 164 through 163, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.0 mm on day of year 158. In the third tube on days of year 152, 160, and 166 the change in soil moisture above the MZFP increased by 0.3, 0.1, and 8.7 mm following a rainfall event of 27 mm on day of year 166. In the absence of rainfall on days of year 150 through 164, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.3 mm on day of year 158.

In the fourth tube on days of year 152, 164, and 166 the change in soil moisture above the MZFP increased by 0.2, 0.8, and 6.7 mm following a rainfall event of 34 mm on day of year 166. In the absence of rainfall on days of year 150 through 164, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.0 mm on day of year 158. In the fifth tube on days of year 158, 160 and 166 the change in soil moisture above the MZFP increased by

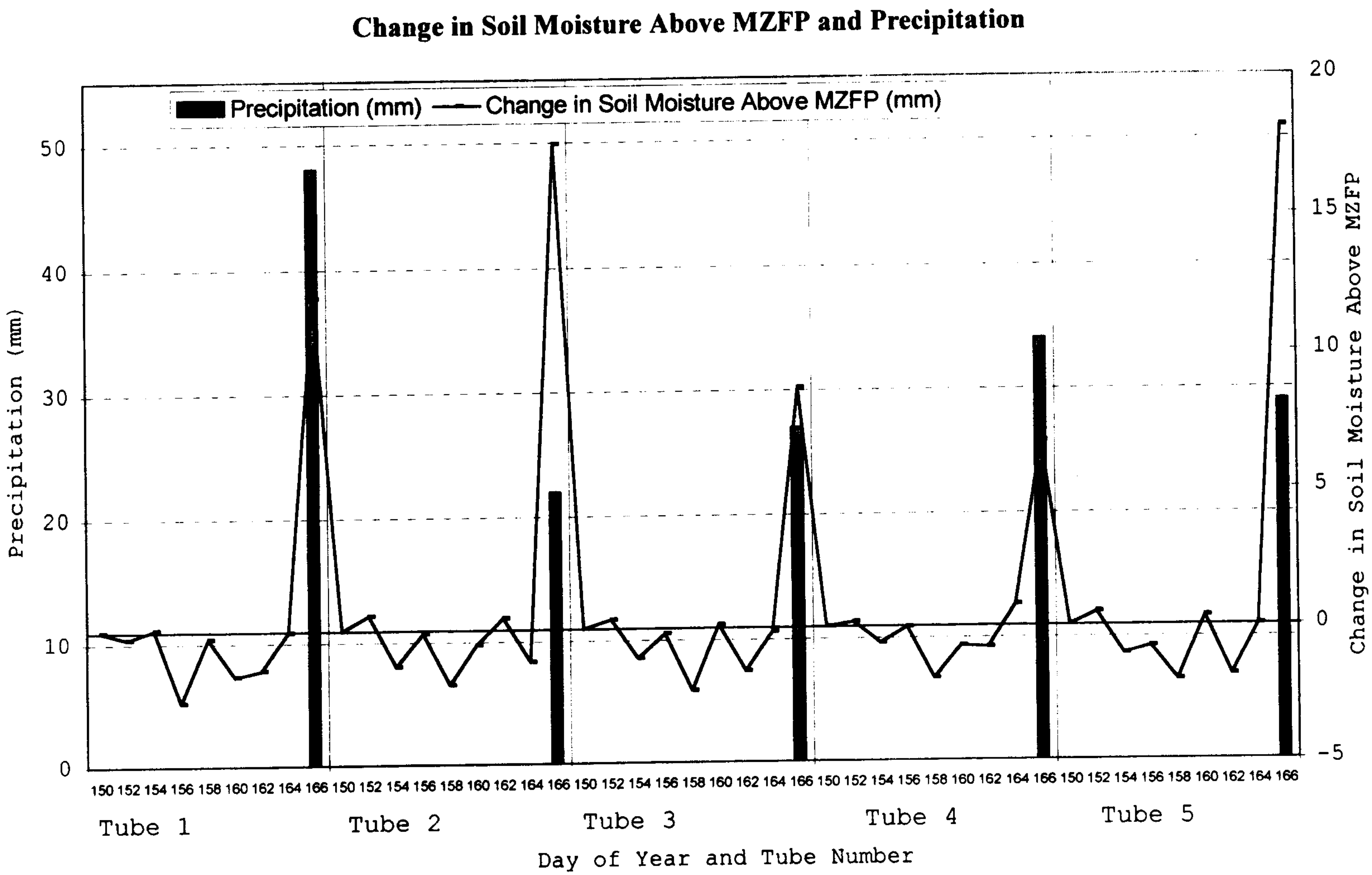

Figure 11. NSA OJP IFC 1 Change in Soil Moisture Above MZFP and Precipitation

0.5, 0.3 and 18.1 mm following a rainfall event of 29 mm on day of year 166. In the absence of rainfall on days of year 150 through 164, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 2.1 mm on day of year 158.

The change in the MZFP versus precipitation is pictured in Figure 12. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 150 through 164, reaching a maximum of 28.8 cm on day of year 158. After the largest rainfall of 48 mm on day of year 166, the MZFP was brought to its minimum value of 22 cm.

In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 150 through 164, reaching a maximum of 36.9 cm on day of year 166. After the largest rainfall of 22 mm on day of year 166 the MZFP was brought to its minimum value of 9.55 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 150 through 164, reaching a maximum of 24.8 cm on day of year 167. After the largest rainfall of 11 mm on day of year 148 followed by 2 mm on day of year 150, the MZFP was brought to its minimum value of 14.8 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 150 through 164, reaching a maximum of 45 cm on days of year 155 and 163. After the largest rainfall of 14 mm on day of year 165 followed by 5 mm on day of year 167, the MZFP was brought to its minimum value of 5.2 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 150 through 164, reaching a maximum of 29.3

Mean Zero-Flux Plane and Precipitation

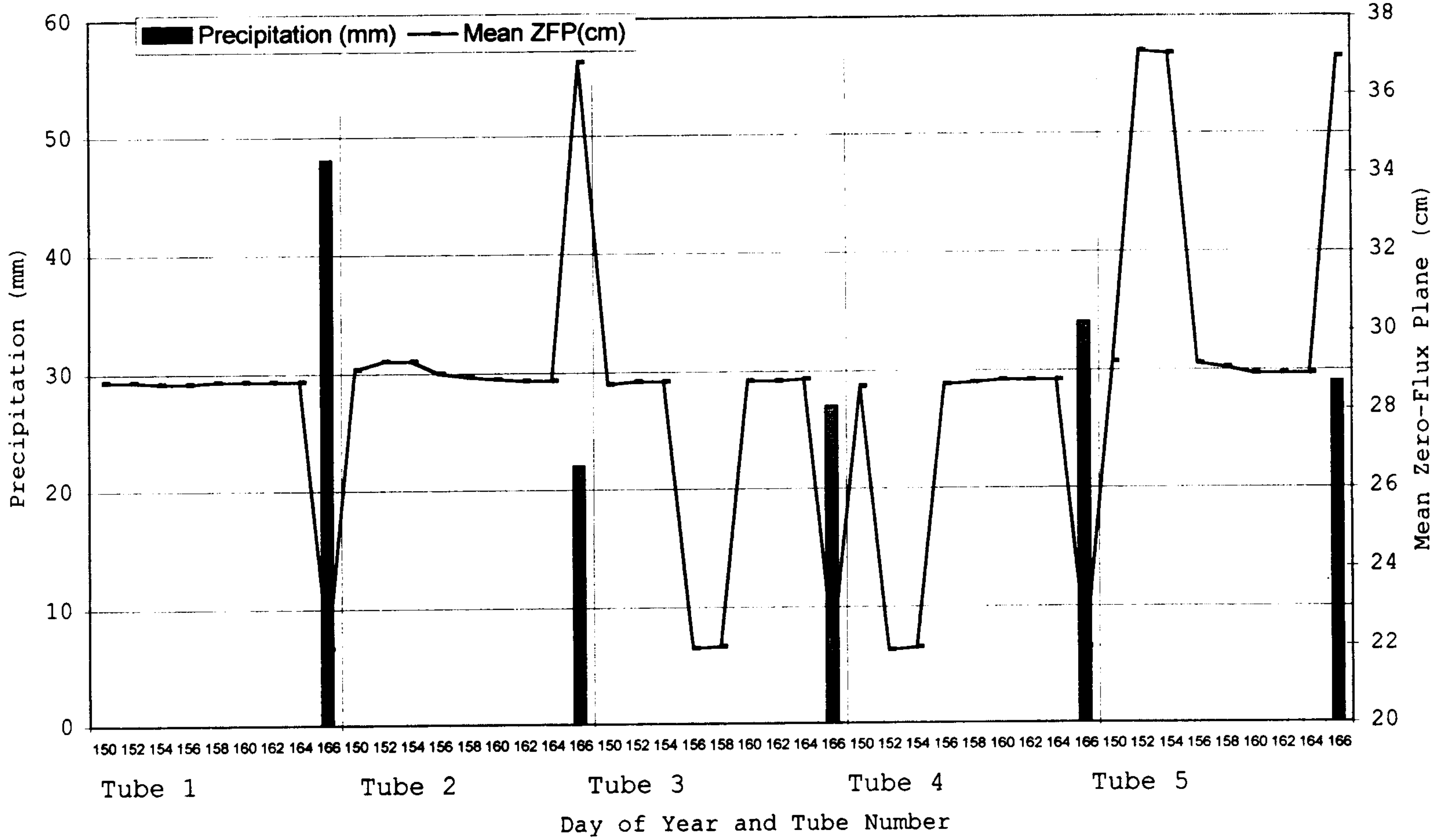

Figure 12. NSA OJP IFC 1 Mean Zero-Flux Plane and Precipitation

cm on day of year 151. The MZFP was brought to its minimum value of 23.3 cm after a rainfall of 6.2 mm on day of year 157.

NSA OJP IFC 2

Measurements were made in five neutron probe access tubes during 1994 on days of year 201 through 219. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 13. In the first tube on days of year 213 and 219 the change in soil moisture above the MZFP increased by 0.1 and 11.5 mm following rainfall events of 21 mm on day of year 201 and 26 mm on day of year 219. In the absence of rainfall on days of year 203 through 217, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 5.0 mm on day of year 203.

In the second tube on day of year 219 the change in soil moisture above the MZFP increased by 9.3 mm following rainfall events of 10 mm on day of year 201 and 10 mm on day of year 219. In the absence of rainfall on days of year 203 through 217, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 4.0 mm on day of year 205. In the third tube on day of year 219 the change in soil moisture above the MZFP increased by 4.7 mm following rainfall events of 18 mm on day of year 201 and 12 mm on day of year 219. In the absence of rainfall on days of year 203 through 217, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 5.6 mm on day of year 203.

In the fourth tube on days of year 213 and 219 the change in soil moisture above the MZFP increased by 0.6 and 5.2 mm following rainfall events of 13 mm on day of year 201 and 15 mm on day of year 219. In the absence of rainfall on days of year 203 through 217, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 3.3 mm on day of

Change in Soil Moisture Above MZFP and Precipitation

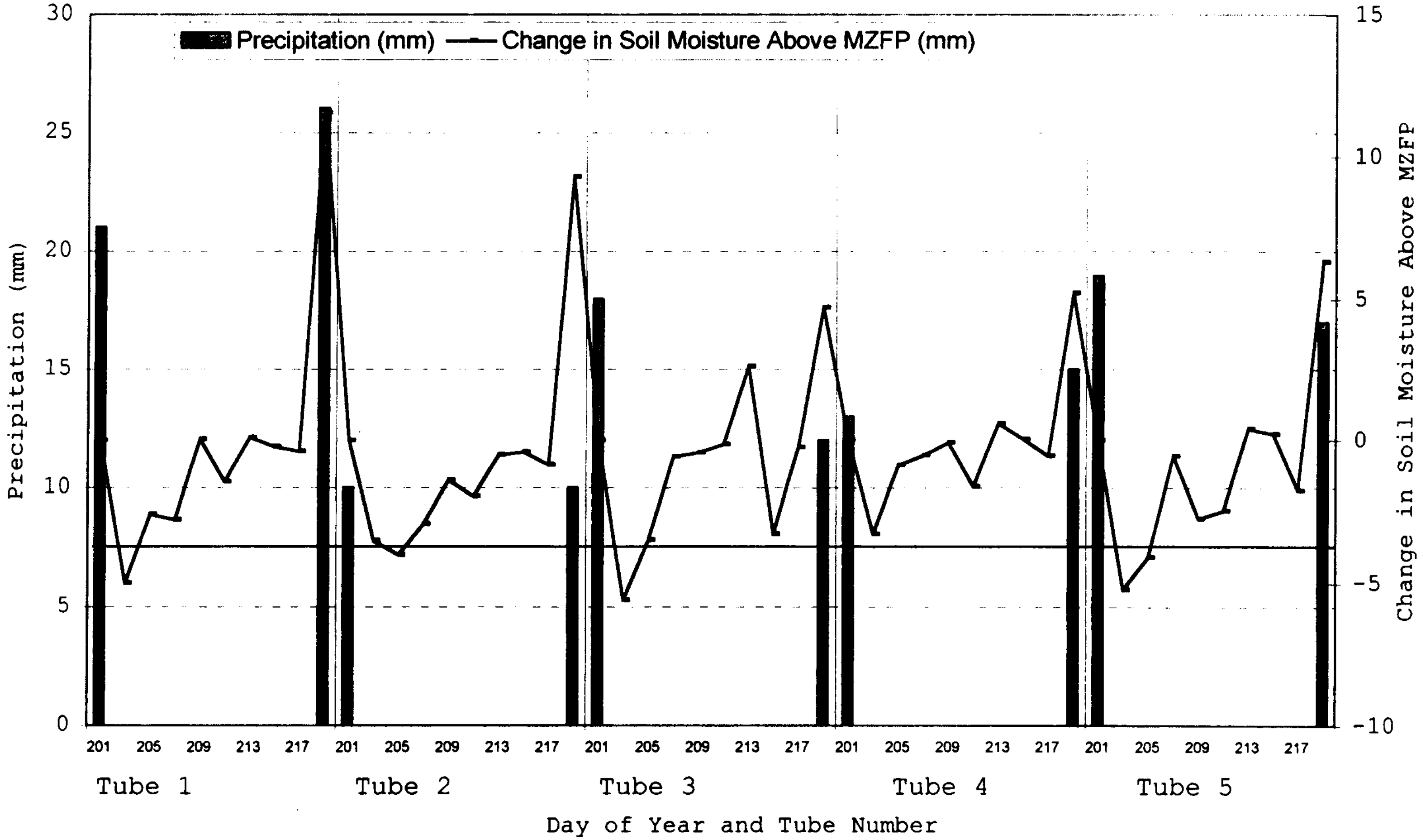

Figure 13. NSA OJP IFC 2 Change in Soil Moisture Above MZFP and Precipitation

year 203. In the fifth tube on days of year 213, 215 and 219 the change in soil moisture above the MZFP increased by 0.4, 0.2, and 6.3 mm following rainfall events of 19 mm on day of year 201 and 17 mm on day of year 219. In the absence of rainfall on days of year 203 through 217, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 5.2 mm on day of year 203.

The change in the MZFP versus precipitation is pictured in Figure 14. In the first access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 203 through 217 reaching a maximum of 65 cm on day of year 205. After the largest rainfall of 26 mm on day of year 219, the MZFP was brought to its minimum value of 20.1 cm.

In the second access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 203 through 217 reaching a maximum of 65 cm on day of year 211. After the largest rainfall of 10 mm on day of year 219 the MZFP was brought to its minimum value of 20.1 cm. In the third access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 203 through 217 reaching a maximum of 65 cm on day of year 203. After the largest rainfall of 18 mm on day of year 201 followed by 12 mm on day of year 219, the MZFP was brought to its minimum value of 20.1 cm.

In the fourth access tube the MZFP moved deeper into the soil profile in the absence of rainfall as on days of year 203 through 217 reaching a maximum of 64.7 cm on day of year 203. After the largest rainfall of 13 mm on day of year 201 followed by 15 mm on day of year 219, the MZFP was brought to its minimum value of 20.1 cm. In the fifth access tube the MZFP moved deeper into the soil profile in the absence of

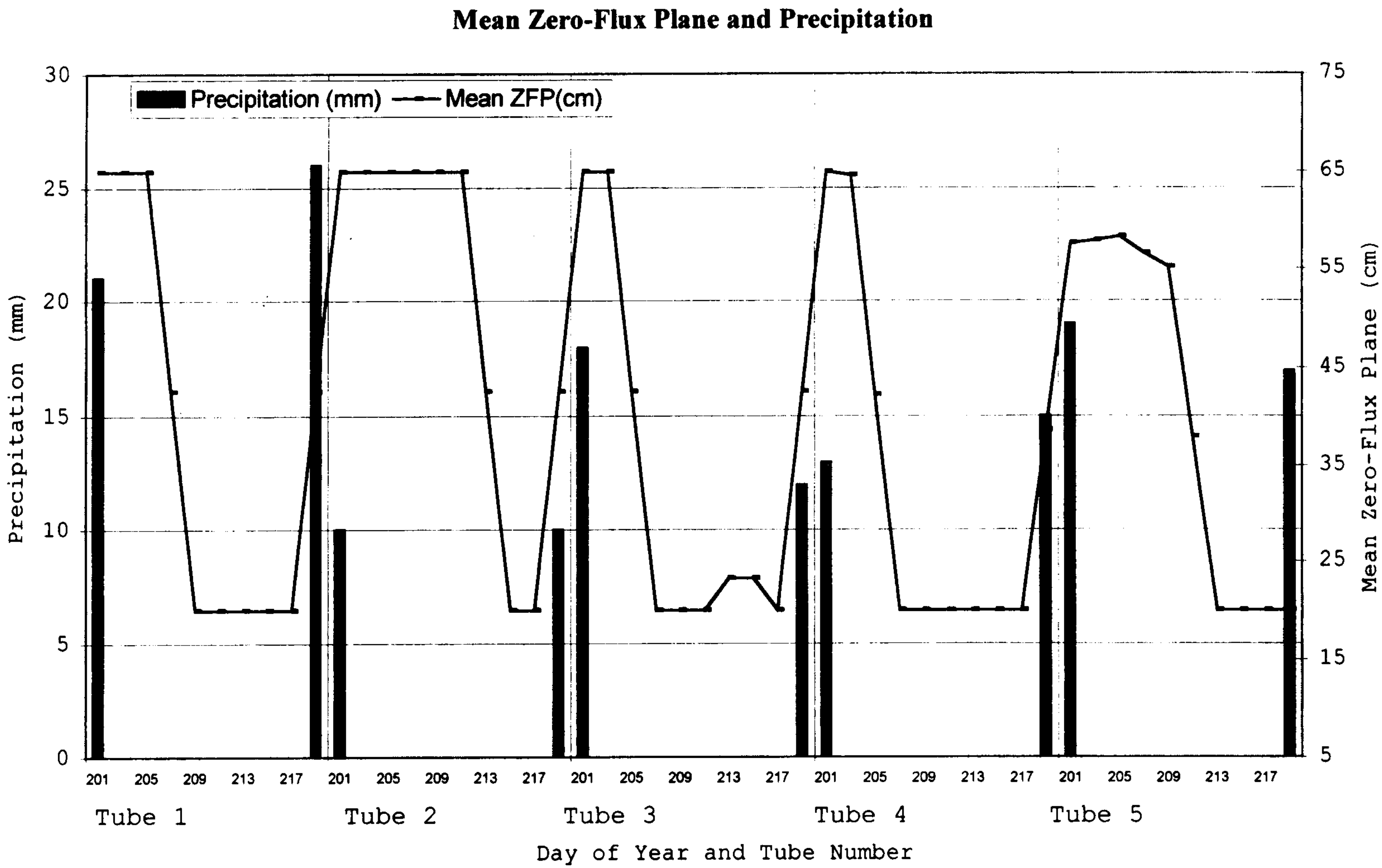

Figure 14. NSA OJP IFC 2 Mean Zero-Flux Plane and Precipitation

rainfall as on days of year 203 through 217 reaching a maximum of 58.6 cm on day of year 205. The MZFP was brought to its minimum value of 20.1 cm after a rainfall event of 19 mm on day of year 201 followed by 17 mm on day of year 219.

NSA YJP IFC 1

Measurements were made in six neutron probe access tubes during 1994 on days of year 150 through 166. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 15. In the second tube on days of year 151, 164 and 166 the change in soil moisture above the MZFP increased by 8.4, 1.2, and 18.3 mm following rainfall events of 9 mm on day of year 151 followed by 31 mm on day of year 166. In the absence of rainfall on days of year 152 through 164, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 5.7 mm on day of year 154.

In the third tube on days of year 151, 152, 164 and 166 the change in soil moisture above the MZFP increased by 7.6, 0.1, 0.4, and 29.2 mm following rainfall events of 3 mm on day of year 151 followed by 29 mm on day of year 166. In the absence of rainfall on days of 152 through 164, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 8.3 mm on day of year 158. In the fourth tube on days of year 151, 164, and 166 the change in soil moisture above the MZFP increased by 7.9, 0.7, and 29.4 mm following rainfall events of 9mm on day of year 151 followed by 31 mm on day of year 166. In the absence of rainfall on days of year 152 through 164, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 4.2 mm on day of year 158.

In the fifth tube on days of year 151, 164, and 166 the change in soil moisture above the MZFP increased by 10.4, 0.2, and 38.6 mm following rainfall events of 13 mm on day of year 151 followed by 47 mm on day of year 166. In the absence of rainfall on days of year 152 through 164, amount of soil moisture above the MZFP

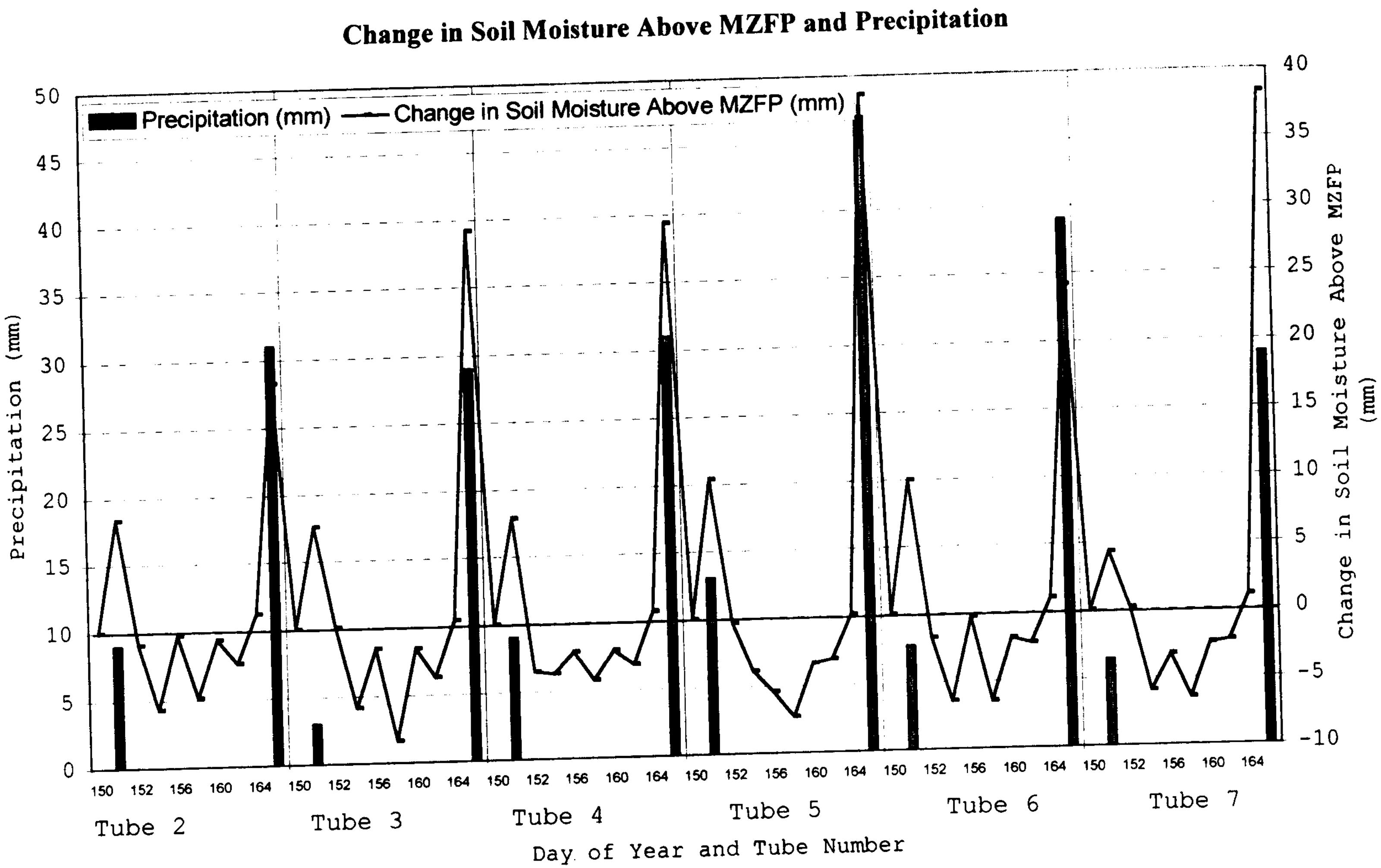

Figure 15. NSA YJP IFC 1 Change in Soil Moisture Above MZFP and Precipitation

decreased indicating the use of soil moisture for evapotranspiration peaking at 7.3 mm on day of year 158. In the sixth tube on days of year 151, 164, and 166 the change in soil moisture above the MZFP increased by 10.0, 1.0, and 24.2 mm following rainfall events of 7.7 mm on day of year 151 followed by 39 mm on day of year 166. In the absence of rainfall on days of 152 through 164, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 6.5 mm on day of year 158. In the seventh tube on days of year 151, 164, and 166 the change in soil moisture above the MZFP increased by 4.3, 1.0, and 38.3 mm following rainfall events of 6.4 mm on day of year 151 followed by 29 mm on day of year 166. In the absence of rainfall on days of year152 through 164, amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 6.5 mm on day of year 158.

The change in the MZFP versus precipitation is pictured in Figure 16. In the second access tube the MZFP remained at a value of 34.9 cm despite a rainfall event of 9 mm on day of year 151 followed by 31 mm on day of year 166. In the third access tube the MZFP remained at a value of 54.9 cm despite a rainfall event of 3 mm on day of year 151 followed by 29 mm on day of year 166.

In the fourth access tube the MZFP remained at a value of 44.9 cm despite a rainfall event of 9 mm on day of year 151 followed by 31 mm on day of year 166. In the fifth access tube the MZFP remained at a value of 44.9 cm despite a rainfall event of 13 mm on day of year 151 followed by 47 mm on day of year 166. In the sixth access tube the MZFP remained at a value of 34.9 cm despite a rainfall event of 7.7 mm on day of year 151 followed by 39 mm on day of year 166. In the seventh access

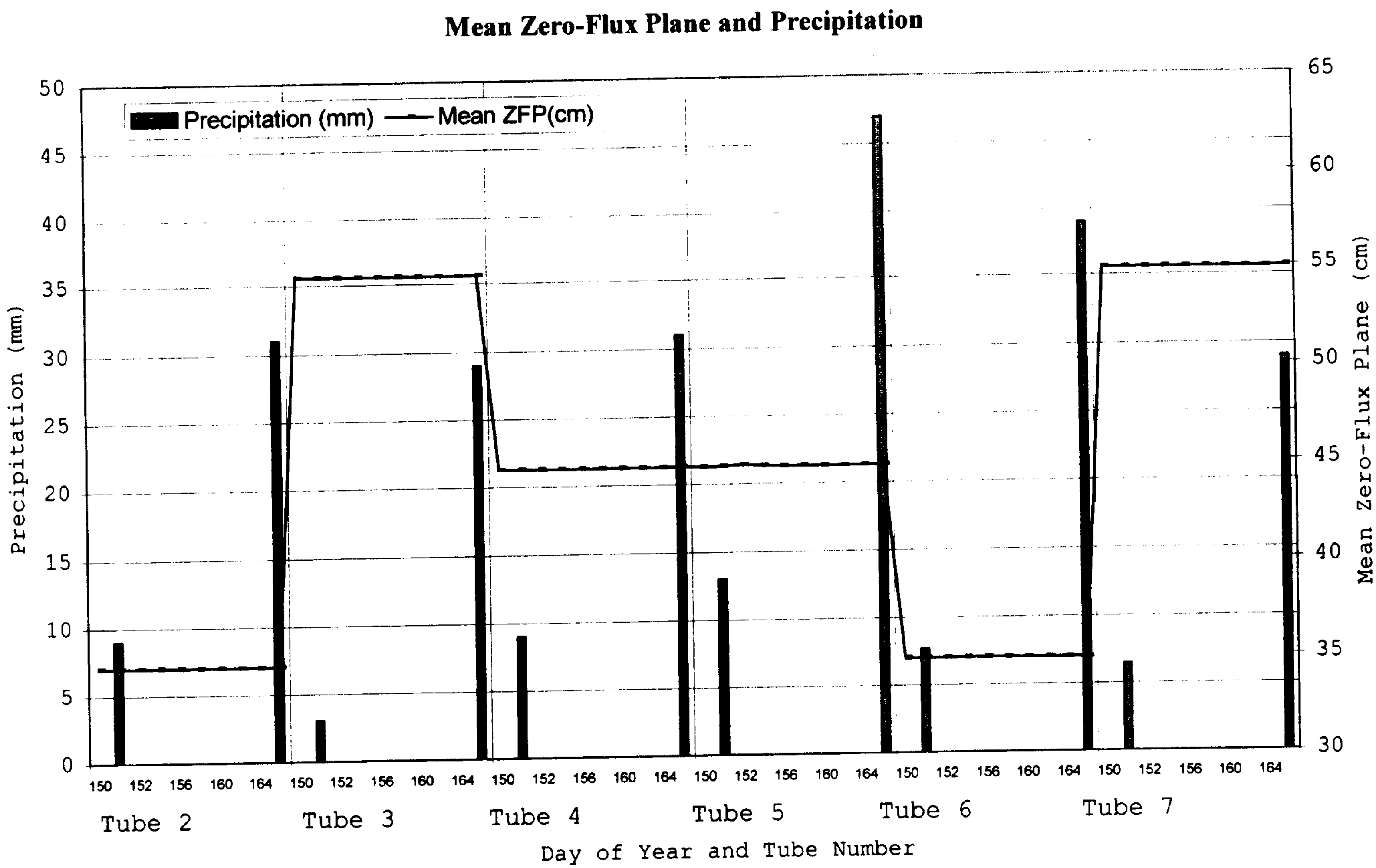

Figure 16. NSA YJP IFC 1 Mean Zero-Flux Plane and Precipitation

tube the MZFP remained at a value of 54.9 cm despite a rainfall event of 6.4 mm on day of year 151 followed by 29 mm on day of year 166.

NSA YJP IFC 2

Measurements were made in four neutron probe access tubes during 1994 on days of year 201 through 219. The change in soil moisture above the MZFP versus precipitation is pictured in Figure 17. In the second tube on days of year 219 the change in soil moisture above the MZFP increased by 7.4 mm. In the absence of rainfall on days of year 205 through 219, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 6.5 mm on day of year 205.

In the third tube on days of year 219 the change in soil moisture above the MZFP increased by 12.1 mm following a rainfall event of 1 mm. In the absence of rainfall on days of year 205 through 217, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 8.1 mm on day of year 205. In the fourth tube on days of year 219 the change in soil moisture above the MZFP increased by 9.9 mm. In the absence of rainfall on days of year 205 through 219, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 7.9 mm on day of year 205. In the fifth tube on days of year 219 the change in soil moisture above the MZFP increased by 15.7 mm. In the absence of rainfall on days of year 205 through 219, the amount of soil moisture above the MZFP decreased indicating the use of soil moisture for evapotranspiration peaking at 8.7 mm on day of year 205.

The change in the MZFP versus precipitation is pictured in Figure 18. In the second access tube the MZFP remained at 34.9 mm in the absence of rainfall as on days of year 205 through 219. The MZFP remained at 34.9 cm despite 14 mm of rainfall on day of year 201 followed by 1 mm on day of year 203. In the third access

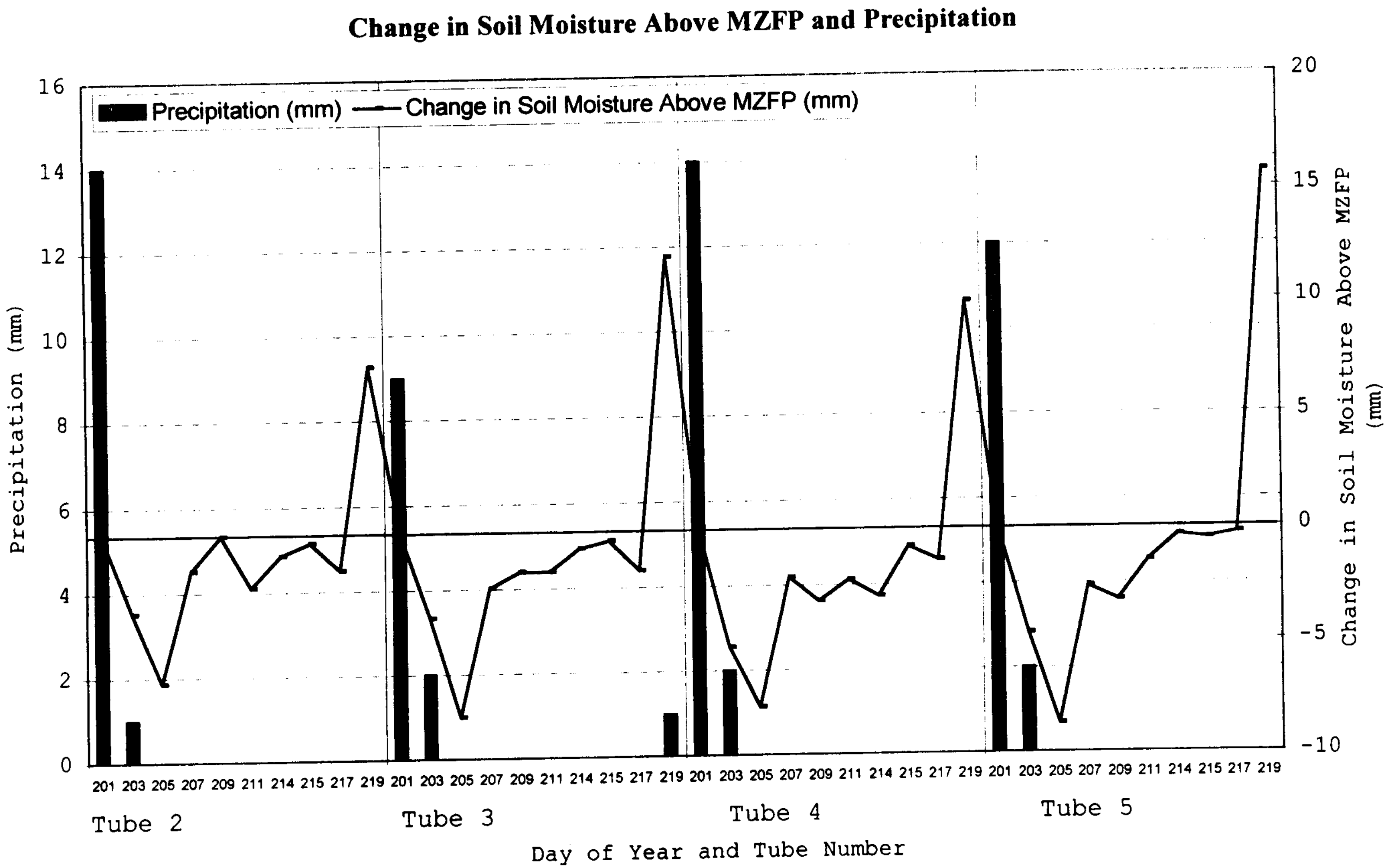

Figure 17. NSA YJP IFC 2 Change in Soil Moisture Above MZFP and Precipitation

tube the MZFP remained at 54.9 mm in the absence of rainfall as on days of year 205 through 219. The MZFP remained at 54.9 cm despite 9 mm of rainfall on day of year 201 followed by 2 mm on day of year 203.

In the fourth access tube the MZFP remained at 44.9 cm in the absence of rainfall as on days of year 205 through 219. The MZFP remained at 44.9 cm despite 14 mm of rainfall on day of year 201 followed by 2 mm on day of year 203. In the fifth access tube the MZFP remained at 44.9 cm in the absence of rainfall as on days of year 205 through 219. The MZFP remained at 44.9 cm despite 12 mm of rainfall on day of year 201 followed by 2 mm on day of year 203.

Mean Zero-Flux Plane and Precipitation

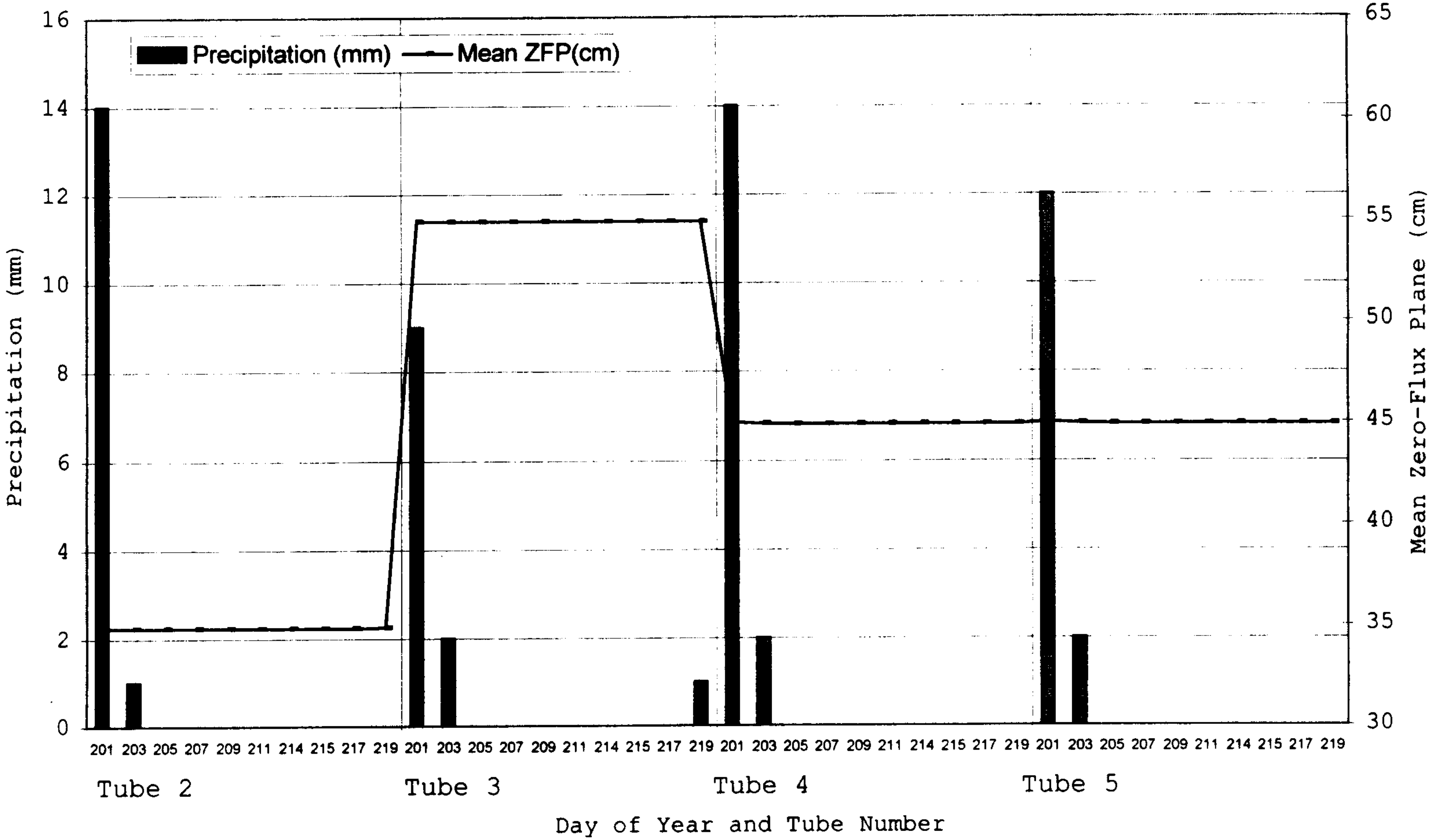

Figure 18. NSA YJP IFC 2 Mean Zero-Flux Plane and Precipitation

DISCUSSION

The Northern and Southern BOREAS Old Jack Pine study sites have, by most standards, relatively uniform course sandy vertical soil profiles with little or no textual variation with depth. The uniformity of the vertical soil profiles at these sites allowed for the proper determination of the mean zero-flux plane with depth and time using The Automated Water Balance Procedure for large-scale experimental databases as presented. The Old Jack Pine sites have higher root zone densities due to the maturity of the stand of trees in the area, resulting in an increased root zone water storage capacity which decreases with depth. This decreased root zone density with depth is attributed to the maturity of the stand of Old Jack Pine trees at the site, the dryness of the soil profile with depth, and the lower soil temperature with depth. The saturated volumetric water content at the Southern Old Jack Pine site was determined to be the highest at $0.40cm^3/cm^3$, while at the Northern Old Jack Pine site this value was determined to be the lowest at $0.21cm^3/cm^3$. The saturated hydraulic conductivity value at a site indicates the rate of moisture movement within the top several meters of the soil profile. The Northern Old Jack Pine site has the lowest value of 77 cm/d and was determined to be the lowest of all the BOREAS study sites. The Southern Old Jack Pine site was determined to have an intermediate value of 146 cm/d. Because of the higher root zone densities found at these sites along with the lower saturated hydraulic conductivity values, the mean zero-flux plane values at the Old Jack Pine sites tended to rise more rapidly following precipitation events.

The Northern and Southern BOREAS Young Jack Pine study sites also have relatively uniform course sandy vertical soil profiles with little or no textual variation with depth. The uniformity of these vertical soil profiles allows for the proper determination of the mean zero-flux plane with depth and time using The Automated Water Balance Procedure for large-scale experimental databases as presented. The Young Jack Pine sites have lower root zone densities compared to the Old Jack Pine sites due to the young age of the stand of trees in the area. This results in a decreased root zone water storage capacity when compared to the Old Jack Pine sites, further decreasing with depth. This decreased root zone density with depth is attributed to the young age of the stand of Young Jack Pine trees at the site, the dryness of the soil profile with depth, and the lowered soil temperature with depth. The saturated volumetric water content at the Southern Old Jack Pine site was determined to be $0.32cm^3/cm^3$, while at the Northern Old Jack Pine site this value was determined to be $0.30cm^3/cm^3$. The saturated hydraulic conductivity value at a site indicates the rate of moisture movement within the top several meters of the soil profile. The Northern Young Jack Pine site has the highest saturated hydraulic conductivity value of all sites, measuring 191 cm/d, with the Southern Young Jack Pine site was measured at the second highest saturated hydraulic conductivity value of 186 cm/d. Because of the lower root zone densities found at the Young Jack Pine sites, along with the higher hydraulic conductivity values, the mean zero-flux plane values at these sites tended to have less significant changes following precipitation events.

RECOMMENDATIONS FOR FUTURE RESEARCH

Several advantages make the zero-flux plane method theoretically more attractive and feasible than other techniques for quantifying the soil water balance of a soil profile. The method is based on measurements made directly in the controlling soil medium integrating the physically-based soil-water dynamics and the soil and plant processes which affect water movement in the soil.

The automated water balance procedure presented here is subject to several inherent sources of error including the improper location of the mean zero-flux plane and the accompanying overestimation or underestimation of the soil water content in the soil profile. On heavy precipitation events the minimum total hydraulic head value might be located at the soil surface although the program will only report the minimum soil sample depth as the depth of the mean zero-flux plane. Thus, it is not possible to accurately determine evapotranspiration in all situations using this automated water balance procedure. For example, the automated water balance procedure underestimates evapotranspiration when there is soil moisture transport across the zero-flux plane by roots. In soil profiles with steady upwards water flow into the soil profile, the automated procedure overrides both evapotranspiration and drainage effects from the soil profile providing inaccurate soil water balance values.

The automated water balance procedure works in soil profiles where the total hydraulic gradient and the soil water content with depth can be determined. This includes soils with textural layering as long as water movement within the soil profile is not hampered. Also, in sites with multiple zero-flux planes, due to precipitation events alternating with periods of drought, the automated procedure will not allow the user to determine the proper location of the zero-flux plane. The automated water balance procedure will fix the zero-flux plane as the lowest interpolated total hydraulic head value, incorrectly assessing the region in the soil profile that is actually contributing to evapotranspiration and drainage. The automated procedure inherently reduces the possibility of visually inspecting the total hydraulic head distribution with depth graph to accurately determine the location of the zero-flux plane on these occasions.

The errors associated with the gravimetric and neutron probe field measurements of the soil water content make the shorter term estimates of the soil water content above the mean zero-flux plane less reliable than the longer term estimates. These errors can be minimized by using more accurate measurement devices or by increasing the number of neutron probe access tubes sampled at each site. This would make shorter term estimates of the soil water content above the mean zero-flux plane more reliable and thereby increase the accuracy of longer term estimates.

The automated water balance procedure is closely related to the traditional soil moisture balance method for estimating soil water content in soil profiles with one major difference. In the traditional soil water balance methods the depth of the mean zero-flux plane is often fixed at the bottom of the "root zone", negating effects of soil water movement in the soil profile. The automated water balance procedure presented here integrates the movement of the mean zero-flux plane within the soil profile resembling more closely actual field conditions.

In conclusion, several distinct advantages make the automated water balance procedure for large-scale experimental databases using the mean zero-flux plane theoretically more attractive than other more traditional techniques. First, it is based on measurements made directly in the controlling soil medium intrinsically integrating the effect of soil hydraulic gradients and soil moisture demand by plant root processes. These movements directly affect soil water movement in the soil profile. Further field testing is needed for different environments and conditions, but it is clear that an automated water balance procedure for large-scale experimental databases using the mean zero-flux plane approach is an effective tool for the analysis of the soil water balance.

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APPENDIX

Appendix Table A. Sample Processed Data SSA OJP IFC 1

Site	Year	DOY	Time	Depth(cm)	TotHd(cm)	ThetaV(%)
2	1994	145	1200	5	108.82	10.17
2	1994	146	1200	5	121.11	9.65
2	1994	148	1200	5	90.73	11.13
2	1994	150	1200	5	109.02	10.16
2	1994	151	1200	5	132.56	9.24
2	1994	153	1200	5	152.15	8.66
2	1994	155	1200	5	152.87	8.64
2	1994	157	1200	5	119.16	9.73
2	1994	159	1200	5	155.69	8.57
2	1994	161	1200	5	199.48	7.65
2	1994	163	1200	5	217.85	7.36
2	1994	165	1200	5	88.15	11.29
2	1994	167	1200	5	95.95	10.82
2	1994	145	1200	15	101.36	11.09
2	1994	146	1200	15	110.64	10.57
2	1994	148	1200	15	107.49	10.74
2	1994	150	1200	15	103.45	10.97
2	1994	151	1200	15	114.8	10.36
2	1994	153	1200	15	128.59	9.75
2	1994	155	1200	15	144.65	9.17
2	1994	157	1200	15	136.45	9.45
2	1994	159	1200	15	144.41	9.18
2	1994	161	1200	15	164.76	8.59
2	1994	163	1200	15	187.93	8.06
2	1994	165	1200	15	112.95	10.45
2	1994	167	1200	15	99.89	11.18
2	1994	145	1200	25	109.15	11.23
2	1994	146	1200	25	113.33	10.97
2	1994	148	1200	25	124.08	10.39
2	1994	150	1200	25	113.74	10.95
2	1994	151	1200	25	121.65	10.51
2	1994	153	1200	25	130.73	10.08
2	1994	155	1200	25	147.63	9.41
2	1994	157	1200	25	153.56	9.21
2	1994	159	1200	25	155.41	9.15
2	1994	161	1200	25	156.12	9.12
2	1994	163	1200	25	173.63	8.62
2	1994	165	1200	25	150.01	9.33
2	1994	167	1200	25	123.3	10.43
2	1994	145	1200	35	129.8	10.61

2	1994	146	1200	35	132.26	10.48
2	1994	148	1200	35	145.26	9.88
2	1994	150	1200	35	132.94	10.45
2	1994	151	1200	35	134.81	10.36
2	1994	153	1200	35	142.69	9.99
2	1994	155	1200	35	158.42	9.38
2	1994	157	1200	35	172.45	8.93
2	1994	159	1200	35	170.92	8.98
2	1994	161	1200	35	176.53	8.81
2	1994	163	1200	35	187.14	8.53
2	1994	165	1200	35	180.34	8.71
2	1994	167	1200	35	152.09	9.61
2	1994	145	1200	45	151.55	10.04
2	1994	146	1200	45	153.26	9.97
2	1994	148	1200	45	162.14	9.61
2	1994	150	1200	45	156	9.85
2	1994	151	1200	45	157.04	9.81
2	1994	153	1200	45	166.33	9.46
2	1994	155	1200	45	181	8.97
2	1994	157	1200	45	197.53	8.52
2	1994	159	1200	45	188.63	8.75
2	1994	161	1200	45	196.33	8.55
2	1994	163	1200	45	204.32	8.35
2	1994	165	1200	45	214.14	8.13
2	1994	167	1200	45	190.01	8.72
2	1994	145	1200	55	164.67	9.91
2	1994	146	1200	55	165.15	9.89
2	1994	148	1200	55	173.49	9.56
2	1994	150	1200	55	171.33	9.64
2	1994	151	1200	55	173.65	9.55
2	1994	153	1200	55	173.87	9.55
2	1994	155	1200	55	192.43	8.93
2	1994	157	1200	55	211.5	8.42
2	1994	159	1200	55	202.59	8.65
2	1994	161	1200	55	212.94	8.39
2	1994	163	1200	55	213.25	8.38
2	1994	165	1200	55	222.4	8.17
2	1994	167	1200	55	209.02	8.48
2	1994	145	1200	65	182.48	9.6
2	1994	146	1200	65	183.55	9.56
2	1994	148	1200	65	196.61	9.11
2	1994	150	1200	65	189.64	9.34
2	1994	151	1200	65	188.01	9.4

2	1994	153	1200	65	191.35	9.28
2	1994	155	1200	65	203.88	8.89
2	1994	157	1200	65	230.1	8.22
2	1994	159	1200	65	222.83	8.39
2	1994	161	1200	65	230.64	8.21
2	1994	163	1200	65	235.5	8.11
2	1994	165	1200	65	241.56	7.98
2	1994	167	1200	65	232.34	8.17
2	1994	145	1200	75	195.83	9.47
2	1994	146	1200	75	200.09	9.32
2	1994	148	1200	75	208.53	9.05
2	1994	150	1200	75	202.68	9.24
2	1994	151	1200	75	203.48	9.21
2	1994	153	1200	75	205.56	9.14
2	1994	155	1200	75	223.64	8.62
2	1994	157	1200	75	235.73	8.32
2	1994	159	1200	75	234.09	8.36
2	1994	161	1200	75	239.13	8.24
2	1994	163	1200	75	249.3	8.03
2	1994	165	1200	75	252.82	7.96
2	1994	167	1200	75	251.82	7.98
2	1994	145	1200	85	202.89	9.58
2	1994	146	1200	85	207.31	9.42
2	1994	148	1200	85	209.71	9.34
2	1994	150	1200	85	209.06	9.36
2	1994	151	1200	85	208.28	9.39
2	1994	153	1200	85	206.82	9.44
2	1994	155	1200	85	225.96	8.83
2	1994	157	1200	85	239.25	8.48
2	1994	159	1200	85	235.6	8.57
2	1994	161	1200	85	249.7	8.23
2	1994	163	1200	85	251.46	8.19
2	1994	165	1200	85	265.67	7.9
2	1994	167	1200	85	266.67	7.88
2	1994	145	1200	95	200.69	10.08
2	1994	146	1200	95	203.92	9.94
2	1994	148	1200	95	213.64	9.55
2	1994	150	1200	95	216.62	9.44
2	1994	151	1200	95	216.27	9.46
2	1994	153	1200	95	212.76	9.59
2	1994	155	1200	95	228.96	9.04
2	1994	157	1200	95	246.6	8.54
2	1994	159	1200	95	242.51	8.65

2	1994	161	1200	95	247.29	8.53
2	1994	163	1200	95	257.63	8.28
2	1994	165	1200	95	264.68	8.12
2	1994	167	1200	95	269.5	8.02
2	1994	145	1200	105	191.93	11.06
2	1994	146	1200	105	194.42	10.91
2	1994	148	1200	105	206.81	10.26
2	1994	150	1200	105	215.01	9.89
2	1994	151	1200	105	220.21	9.68
2	1994	153	1200	105	216.88	9.82
2	1994	155	1200	105	231.16	9.29
2	1994	157	1200	105	243.68	8.89
2	1994	159	1200	105	244.39	8.87
2	1994	161	1200	105	252.43	8.65
2	1994	163	1200	105	258.51	8.49
2	1994	165	1200	105	261.22	8.43
2	1994	167	1200	105	262.63	8.39
2	1994	145	1200	115	174.98	13.22
2	1994	146	1200	115	177.11	13
2	1994	148	1200	115	187.52	12.06
2	1994	150	1200	115	206.95	10.77
2	1994	151	1200	115	212.02	10.5
2	1994	153	1200	115	215.87	10.3
2	1994	155	1200	115	223.13	9.97
2	1994	157	1200	115	233.67	9.55
2	1994	159	1200	115	237.3	9.42
2	1994	161	1200	115	237.65	9.41
2	1994	163	1200	115	245.41	9.15
2	1994	165	1200	115	243.62	9.2
2	1994	167	1200	115	249.44	9.02
2	1994	145	1200	125	155.97	18.22
2	1994	146	1200	125	159.58	17.28
2	1994	148	1200	125	168.31	15.49
2	1994	150	1200	125	175.72	14.34
2	1994	151	1200	125	188.61	12.85
2	1994	153	1200	125	190.19	12.69
2	1994	155	1200	125	202.08	11.71
2	1994	157	1200	125	208.94	11.24
2	1994	159	1200	125	207.89	11.31
2	1994	161	1200	125	212.31	11.03
2	1994	163	1200	125	211.1	11.11
2	1994	165	1200	125	217.45	10.74
2	1994	167	1200	125	216.56	10.79

2	1994	145	1200	135	156.65	21.56
2	1994	146	1200	135	157.53	21.17
2	1994	148	1200	135	160.03	20.16
2	1994	150	1200	135	166.78	18
2	1994	151	1200	135	173.66	16.37
2	1994	153	1200	135	178.93	15.38
2	1994	155	1200	135	184.86	14.46
2	1994	157	1200	135	192.29	13.52
2	1994	159	1200	135	187.95	14.04
2	1994	161	1200	135	190.32	13.75
2	1994	163	1200	135	193.22	13.41
2	1994	165	1200	135	193.55	13.37
2	1994	167	1200	135	194.29	13.29
2	1994	145	1200	145	166.58	21.59
2	1994	146	1200	145	166.33	21.71
2	1994	148	1200	145	166.67	21.55
2	1994	150	1200	145	168.81	20.63
2	1994	151	1200	145	173.61	18.92
2	1994	153	1200	145	180.22	17.13
2	1994	155	1200	145	188.19	15.51
2	1994	157	1200	145	194.02	14.58
2	1994	159	1200	145	192.36	14.83
2	1994	161	1200	145	193.41	14.67
2	1994	163	1200	145	195.25	14.41
2	1994	165	1200	145	198.39	13.99
2	1994	167	1200	145	197	14.17
2	1994	145	1200	155	177.56	21.15
2	1994	146	1200	155	177.51	21.18
2	1994	148	1200	155	178.02	20.96
2	1994	150	1200	155	178.09	20.93
2	1994	151	1200	155	179.89	20.21
2	1994	153	1200	155	184.68	18.6
2	1994	155	1200	155	192.69	16.57
2	1994	157	1200	155	196.53	15.81
2	1994	159	1200	155	196.73	15.77
2	1994	161	1200	155	197.25	15.68
2	1994	163	1200	155	200.03	15.2
2	1994	165	1200	155	201.47	14.97
2	1994	167	1200	155	202.96	14.74
2	1994	145	1200	165	193.61	18.93
2	1994	146	1200	165	193.56	18.94
2	1994	148	1200	165	194.07	18.78
2	1994	150	1200	165	193.08	19.09

2	1994	151	1200	165	194.67	18.6
2	1994	153	1200	165	195.53	18.35
2	1994	155	1200	165	201.03	16.94
2	1994	157	1200	165	206.53	15.81
2	1994	159	1200	165	206.22	15.87
2	1994	161	1200	165	207.76	15.59
2	1994	163	1200	165	210.26	15.16
2	1994	165	1200	165	212.66	14.78
2	1994	167	1200	165	212.95	14.74

Appendix Table B. SSA OJP IFC 1 Main Program

```
Private Sub SSAOJPIFC1mnu_Click()
  Static warr(2600) As Double
  Static Depth(1000) As Double
  Static TotHd(1000) As Double
  Static ThetaV(1000) As Double
  Static deriv(100) As Double
  Static derivz(100) As Double
  Dim ThisDay As Variant, Precippt As Variant
  Dim zfp_size As Integer, TubeNum As Integer
  Dim tsm_size As Integer, site As Integer, i As Integer
  Static h(100) As Double
  Static hz(100) As Double
  Dim Clemency As Double, DepthSteps As Double, x1 As Double
  Dim TubeDepth As Integer, dummy As Integer, dummyz As Integer
  Dim X As Double, Y As Double, keep As Double, x0 As Double
  Dim DeltaSMaboveMZFP As Double, ChangeTotalSM As Double
  Dim DeltaSDbelowMZFP As Double
  Dim area As Double, dzfp As Double, MeanZFP As Double
  Clemency = 0.0000000000001
'*********************************************************************
'Open file handles for read and write access as input and output files
'*********************************************************************
Open "a:\sopi1.csv" For Input As #1
Open "a:\sopis1.csv" For Output As #2
'*********************************************************************
'Read input data file and linearly interpolate back to depth zero
'*********************************************************************
Do While Not EOF(1)
 Input #1, TubeNum, ThisDay, Depth(2), TotHd(2), ThetaV(2), Precip
 Input #1, TubeNum, ThisDay, Depth(3), TotHd(3), ThetaV(3), Precippt
 Depth(1) = -5
 TotHd(1) = (TotHd(2) + (TotHd(2) - TotHd(3)))
```

```
ThetaV(1) = (ThetaV(2) - (ThetaV(3) - ThetaV(2)))
Depth(0) = -15
TotHd(0) = (TotHd(1) + (TotHd(1) - TotHd(2)))
ThetaV(0) = (ThetaV(1) - (ThetaV(2) - ThetaV(1)))
Input #1, TubeNum, ThisDay, Depth(4), TotHd(4), ThetaV(4), Precippt
Input #1, TubeNum, ThisDay, Depth(5), TotHd(5), ThetaV(5), Precippt
Input #1, TubeNum, ThisDay, Depth(6), TotHd(6), ThetaV(6), Precippt
Input #1, TubeNum, ThisDay, Depth(7), TotHd(7), ThetaV(7), Precippt
Input #1, TubeNum, ThisDay, Depth(8), TotHd(8), ThetaV(8), Precippt
Input #1, TubeNum, ThisDay, Depth(9), TotHd(9), ThetaV(9), Precippt
Input #1, TubeNum, ThisDay, Depth(10), TotHd(10), ThetaV(10), Precippt
Input #1, TubeNum, ThisDay, Depth(11), TotHd(11), ThetaV(11), Precippt
Input #1, TubeNum, ThisDay, Depth(12), TotHd(12), ThetaV(12), Precippt
Input #1, TubeNum, ThisDay, Depth(13), TotHd(13), ThetaV(13), Precippt
Input #1, TubeNum, ThisDay, Depth(14), TotHd(14), ThetaV(14), Precippt
Input #1, TubeNum, ThisDay, Depth(15), TotHd(15), ThetaV(15), Precippt
Input #1, TubeNum, ThisDay, Depth(16), TotHd(16), ThetaV(16), Precippt
Input #1, TubeNum, ThisDay, Depth(17), TotHd(17), ThetaV(17), Precippt
Input #1, TubeNum, ThisDay, Depth(18), TotHd(18), ThetaV(18), Precippt
'**********************************************************************
'Declare local variables and fill derivative array with slope and height values
'Cubic Spline Minimum/Maximum routine to evaluate daily zero-flux plane
'**********************************************************************
 TubeDepth = 19
 FullDepth = Depth(18)
 ThetaSat = 0.4
 DepthSteps = 0.1
 keep = 1E+105
 DerivTotHd = getDerivatives(Depth(), TotHd(), TubeDepth, deriv(), h(), Clemency)
For X = 0 To FullDepth Step DepthSteps
   InterpTotHd = Spline(Depth(), TotHd(), deriv(), h(), TubeDepth, X)
'**********************************************************************
'To obtain third file with cubic interpolation values, add third file handle for output of
'variable "InterpTotHd" here.
```

```
'*********************************************************************
   If (X > 5) And (Y < keep) Then
      dzfp = X
      keep = Y
   End If
Next X
'*********************************************************************
'Calculate Mean Zero-Flux Plane for two day count
'*********************************************************************
If ThisDay = 145 Then
MeanZFP = dzfp
Else: MeanZFP = (dzfp + keepzfp) / 2
End If
keepzfp = dzfp
'*********************************************************************
'Print first output file
'*********************************************************************
 Print #2, TubeNum, ",", ThisDay, ",", Depth(2), ",", TotHd(2), ",", ThetaV(2), ",", dzfp, ",", 
MeanZFP, ",", Precip
 Print #2, TubeNum, ",", ThisDay, ",", Depth(3), ",", TotHd(3), ",", ThetaV(3)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(4), ",", TotHd(4), ",", ThetaV(4)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(5), ",", TotHd(5), ",", ThetaV(5)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(6), ",", TotHd(6), ",", ThetaV(6)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(7), ",", TotHd(7), ",", ThetaV(7)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(8), ",", TotHd(8), ",", ThetaV(8)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(9), ",", TotHd(9), ",", ThetaV(9)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(10), ",", TotHd(10), ",", ThetaV(10)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(11), ",", TotHd(11), ",", ThetaV(11)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(12), ",", TotHd(12), ",", ThetaV(12)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(13), ",", TotHd(13), ",", ThetaV(13)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(14), ",", TotHd(14), ",", ThetaV(14)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(15), ",", TotHd(15), ",", ThetaV(15)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(16), ",", TotHd(16), ",", ThetaV(16)
 Print #2, TubeNum, ",", ThisDay, ",", Depth(17), ",", TotHd(17), ",", ThetaV(17)
```

```
Print #2, TubeNum, ",", ThisDay, ",", Depth(18), ",", TotHd(18), ",", ThetaV(18)
Loop
Close #1
Close #2
'*********************************************************************
'Open second set of file handles for data input and data output
'Print header for output file
'*********************************************************************
Open "a:\sopis1.csv" For Input As #1
Open "a:\sopif1.csv" For Output As #2
Print #2, "SOUTHERN STUDY AREA  - OLD JACK PINE - INTENSIVE FIELD
CAMPAIGN ONE"
Print #2, " Automated  Water  Balance Procedure  for Large-Scale Databases Based on  Soil
Moisture"
Print #2, " Susana Maria Grayson _______________________________________(Copyright
1996)"
Print #2, "Tube"; ","; "DOY"; ","; "DOY ZFP "; ","; "Mean ZFP"; ", "; "Precip"; ",";
Print #2, "Delta SSM Above"; ", "; "Delta TSM"; ", "; "Drainage Below"
Print #2, ""; ","; ""; ","; "(cm)"; ","; "(cm)"; ","; "(mm)"; ","; "Mean ZFP(mm)";
Print #2, ","; "(mm)"; ","; "Mean ZFP(mm)"
Do While Not EOF(1)
Input #1, TubeNum, ThisDay, Depth(2), TotHd(2), ThetaV(2), dzfp, MeanZFP, Precip
Input #1, TubeNum, ThisDay, Depth(3), TotHd(3), ThetaV(3)
Input #1, TubeNum, ThisDay, Depth(4), TotHd(4), ThetaV(4)
Input #1, TubeNum, ThisDay, Depth(5), TotHd(5), ThetaV(5)
Input #1, TubeNum, ThisDay, Depth(6), TotHd(6), ThetaV(6)
Input #1, TubeNum, ThisDay, Depth(7), TotHd(7), ThetaV(7)
Input #1, TubeNum, ThisDay, Depth(8), TotHd(8), ThetaV(8)
Input #1, TubeNum, ThisDay, Depth(9), TotHd(9), ThetaV(9)
Input #1, TubeNum, ThisDay, Depth(10), TotHd(10), ThetaV(10)
Input #1, TubeNum, ThisDay, Depth(11), TotHd(11), ThetaV(11)
Input #1, TubeNum, ThisDay, Depth(12), TotHd(12), ThetaV(12)
Input #1, TubeNum, ThisDay, Depth(13), TotHd(13), ThetaV(13)
Input #1, TubeNum, ThisDay, Depth(14), TotHd(14), ThetaV(14)
Input #1, TubeNum, ThisDay, Depth(15), TotHd(15), ThetaV(15)
```

```
 Input #1, TubeNum, ThisDay, Depth(16), TotHd(16), ThetaV(16)
 Input #1, TubeNum, ThisDay, Depth(17), TotHd(17), ThetaV(17)
 Input #1, TubeNum, ThisDay, Depth(18), TotHd(18), ThetaV(18)
'*********************************************************************
'Fill DerivThetaV array with value and derivative of thetav array values
'Integrate thetav array from Mean Zero-Flux Plane value to depth zero
'Result is Change in Soil Water Content above Mean Zero-Flux Plane for period of interest
'*********************************************************************
   DerivThetaV = getDerivatives(Depth(), ThetaV(), TubeDepth, derivz(), hz(), Clemency)
   X = 0
   zfp_size = MeanZFP / DepthSteps
      For I = 0 To zfp_size - 1
      warr(i) = Spline(Depth(), ThetaV(), derivz(), hz(), TubeDepth, X)
      X = X + DepthSteps
      Next I
      DeltaSMaboveMZFP = (Simpson(zfp_size, warr(), DepthSteps)) / 10
'*********************************************************************
'Once array of derivative and value of thetav filled
'Integrate thetav array from full sample depth to depth zero
'Resultant value is the Change in Total Soil Moisture for period of interest
'*********************************************************************
   X = 0
   tsm_size = FullDepth / DepthSteps
      For I = 0 To tsm_size - 1
      warr(i) = Spline(Depth(), ThetaV(), derivz(), hz(), TubeDepth, X)
      X = X + DepthSteps
      Next i
      ChangeTotalSM = (Simpson(tsm_size, warr(), DepthSteps)) / 10
'*********************************************************************
'Calculate Change in Soil Drainagae below Mean Zero-Flux Plane
'Calculate soil capacity of specific site given value of Theta at Saturation
'Allocate precipitation accordingly
'*********************************************************************
DeltaSDbelowMZFP = ChangeTotalSM - DeltaSMaboveMZFP
```

```
If (Precip > (DeltaSMaboveMZFP - (ThetaSat * MeanZFP))) Then
DeltaSDbelowMZFP = DeltaSDbelowMZFP + Precip
Else: DeltaSMaboveMZFP = DeltaSMaboveMZFP + Precip
End If
'**********************************************************************
'Print resultant values to output file
'**********************************************************************
If ThisDay = 145 Then
Print #2, TubeNum; ","; ThisDay; ","; dzfp ; ","; "  "; ","; Precip;
Print #2, ","; DeltaSMaboveMZFP; ","; ChangeTotalSM; ","; DeltaSDbelowMZFP
Else
Print #2, TubeNum; ","; ThisDay; ","; dzfp; ","; MeanZFP; ","; Precip;
Print #2, ","; DeltaSMaboveMZFP; ","; ChangeTotalSM; ","; DeltaSDbelowMZFP
End If
Loop
'**********************************************************************
'Close file handles and exit function
'**********************************************************************
Close #1
Close #2
End Sub
```

Appendix Table C. Total Hydraulic Head and Soil Water Content Data Interpolation Function

```
Function CubicSpline (Depth ( ) As Double, TotalHH ( ) As Double, Derivative ( ) As
Double, Height ( ) As Double, NumDepths As Integer, Clemency As Double) As Double
'*************************************************************************
'Function CubicSpline keeps table of observed values and returns matrix of interpolated
'values at DepthStep intervals. Uses different polynomials to connect adjacent points with
'third degree cubic polynomial. First derivatives at each point fixed, second derivatives set
'at end points. Degenerate version of Gaussian elimination to calculate coefficients. 'Natural
end-points assumed, second derivatives at first and last point set to zero.
'*************************************************************************
Dim CubicSpline as Double

For I = 0 to (NumDepths - 1)
        If [{Clemency < Depth (I)} Or {Clemency > Depth (I + 1 )}] Then
        I = I + 1
        End If
Next I

CubicSpline =

[Depth (I+1) - Clemency ] * [TotalHH (I) / Height (I+1) - Derivative (I-1) * Height (I+1) / 6]
+ [Clemency - Depth (I)] * [TotalHH (I+1) / Height (I+1) - Derivative (I) * Height (I+1) / 6]
+ [Derivative (I-1) * (Depth (I+1) - Clemency) ^ 3]/ [6 * Height (I+1)] + [Derivative (I) *
(Clemency - Depth (I)) ^ 3] / [6 * Height (I+1))]

End Function
```

Appendix Table D. Tridiagonal Matrix Private Function

```
Private Function TriDiMatrix(ElementNum As Integer, SubDiagonal() As Double, Diagonal()
As Double, SuperDiagonal() As Double, d() As Double, Clemency As Double) As Integer
'
*******************************************************************************
' The function "TriDiMatrix" solves the tridiagonal matrix created in the function "FindDeriv"
call.
'This is a banded matrix which only contains elements directly above, on, or below the diagonal
as
' non-zero.  This is a symmetric tridiagonal solved with a degenerate version of the
' Gaussian Elimination method.
10/96 SMG
'*******************************************************************************
*
' Forward elimination of SubDiagonal matrix elements - only elements j = I + 1 and k = I + 1
need to
'be evaluated since elements [ I , k ] equal to zero for each k > I + 1.
'*******************************************************************************
*
 For iCounter = 1 To ElementNum - 1
  If [Diagonal ( )< Clemency] Then Exit For
        SubDiagonal ( iCounter ) = SubDiagonal ( iCounter )  /  Diagonal ( iCounter - 1
)
        Diagonal ( iCounter ) = Diagonal ( iCounter ) -
                    SubDiagonal ( iCounter )  *  SuperDiagonal ( iCounter
- 1 )
        d ( iCounter )  =  d ( iCounter ) - SubDiagonal ( iCounter )  *  d ( iCounter - 1 )
 Next iCounter
'*******************************************************************************
*
'The case k = I not evaluated since equal to zero an element of an array never evaluated again.
'*******************************************************************************
*
 If [Diagonal () < Clemency] Then
            d(ElementNum - 1) = d(ElementNum - 1) / Diagonal(ElementNum - 1)
      For iCounter = ElementNum - 2 To 0 Step -1
            d(iCounter) = (d(iCounter) -
                    SuperDiagonal(iCounter) * d(iCounter + 1)) /
Diagonal(iCounter)
      Next iCounter
 End If
End Function
```

Appendix Table E. Total Hydraulic Head and Soil Moisture Derivative Function

```
Function FindDeriv (NumDepth () As Double, SplineValue() As Double, Depth As Integer,
Derivative () As Double, HeightValue () As Double, Clemency As Double) As Integer

'*************************************************************************
*****
'FindDeriv function used by cubic spline interpolation subroutine to find second derivatives,
using 'degenerate version of Gaussian elimination method
SMG 10/96
'*************************************************************************
******
 Dim SubDiagonal ( Depth )
 Dim Diagonal ( Depth )
 Dim SuperDiagonal ( Depth )
'*************************************************************************
******
'Transform augmented matrix [ SplineValue | Depth] into augmented matrix of linear systems
to row 'echelon form
'*************************************************************************
******
        For iCounter = 1 To Depth - 1
                HeightValue ( iCounter ) = - NumDepth (iCounter - 1) + NumDepth (
iCounter )
                Derivative ( iCounter ) = ( SplineValue ( iCounter ) -
                                          SplineValue (iCounter - 1) ) / HeightValue
( iCounter )
        Next iCounter
'*************************************************************************
******
'Form augmented matrix, transform matrix to row echelon using elementary row operation
'*************************************************************************
******
        For iCounter = 1 To Depth - 2
                Diagonal ( jCounter ) = 2
                SuperDiagonal ( iCounter - 1 ) = HeightValue ( iCounter + 1)
                                          / ( HeightValue (iCounter ) + HeightValue
(iCounter + 1 ) )
                SubDiagonal ( iCounter - 1 ) = 1 - SuperDiagonal ( iCounter - 1)
                Derivative ( iCounter - 1 ) = 6 * ( Derivative ( iCounter + 1) - Derivative
( iCounter ) )                              / ( HeightValue ( iCounter ) +
HeightValue ( iCounter + 1 ) )
        Next iCounter
'*************************************************************************
******
'Solve linear system corresponding to matrix in row echelon form obtained in prior counter
loop
'use back substitution
'*************************************************************************
******
```

```
        For iCounter = 1 To Depth - 3
                SubDiagonal(iCounter) = SubDiagonal(iCounter) / Diagonal(iCounter -
1)
                Diagonal(iCounter) = Diagonal(iCounter) - SubDiagonal(iCounter)
                                        *  SuperDiagonal(iCounter - 1)
                Derivative(iCounter) = Derivative(iCounter) - SubDiagonal(iCounter) *
                                           Derivative(iCounter - 1)
        Next iCounter
                Derivative(Depth - 3) = Derivative(Depth - 3) / Diagonal(Depth - 3)
        For iCounter = Depth - 3 To 0 Step -1
                Derivative(iCounter) = (Derivative(iCounter) -
SuperDiagonal(iCounter) *
                                        Derivative(iCounter + 1)) /  Diagonal(iCounter)
        Next iCounter
End Function
```

Appendix Table F. Change in Soil Moisture Function

```
Function ChangeInSoilMoisture (zfp_size as integer, InterpolatedSoilMoisture ( ) as double,
DeltaX as double) as double
'**************************************************************************
*
'ChangeInSoilMoisture routine evaluates amount of soil water content at tube site given arrays
of 'Soil Water Content versus Depth at tube site using Simpson's one-third rule after filling
cubic 'interpolation array matrix and keeping table of observed values.
SMG 10/96
'**************************************************************************
*
Dim ChangeInSoilMoisture as Double
'**************************************************************************
*
'First and second inner-loop evaluation routines - first and second approximations
'**************************************************************************
*

For I = 0 to ( zfp_size -1 ) step 2
     For I = 1 to ( zfp_size - 2 ) step 2
      If ( zfp_size mod 2 ) <> 0 Then
        zfp_size = zfp_size - 1
      End If
        SecondLoop = SecondLoop + InterpolatedSoilMoisture ( )
    Next I
        FirstLoop = FirstLoop + InterpolatedSoilMoisture ( )
Next I

'**************************************************************************
*
'Third inner-loop evaluation routine - refine approximation.
'**************************************************************************
*

If ( zfp_size mod 2 ) <> 0 Then
       ChangeInSoilMoisture = 2 * FirstLoop + 4 * SecondLoop +
                         DeltaX / 3 * ( InterpolatedSoilMoisture ( 0 ) +
                          InterpolatedSoilMoisture (zfp_size - 1 ) )

'**************************************************************************
*
'Add successive approximations
'**************************************************************************
*
Else:
    zfp_ size = zfp_size + 1
              ChangeInSoilMoisture =
```

```
                        ChangeInSoilMoisture + DeltaX / 2 *
                        (InterpolatedSoilMoisture (zfp_size - 2) +
                        InterpolatedSoilMoisture (zfp_size - 1 ))
End If

End Function
```

Appendix Table G. SSA OJP IFC 1 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	145	31.2	31.2	0.0	0.0	0.0	4	34.9	165.3	200.2	0.0
1	146	33.2	32.2	-2.0	-0.6	-2.6	4	34.1	163.5	197.6	0.0
1	148	5.2	19.2	3.4	-2.9	0.5	8	22.9	175.2	198.1	0.0
1	150	34.6	19.9	-2.7	-0.4	-3.1	2	21.0	174.0	195.1	0.0
1	151	34.7	34.6	-1.8	-5.0	-6.9	0	36.2	152.0	188.2	0.0
1	153	35.3	35.0	-1.9	-7.1	-9.0	0	34.8	144.4	179.2	0.0
1	155	31.9	33.6	-1.6	-14.8	-16.4	1	31.7	131.1	162.8	0.0
1	157	5.2	18.5	0.7	-10.1	-9.4	4	17.7	135.7	153.4	0.0
1	159	29.7	17.4	-1.5	-1.5	-3.0	0	15.2	135.2	150.4	0.0
1	161	34.9	32.3	-2.0	-2.7	-4.7	0	26.9	118.8	145.7	0.0
1	163	35.0	34.9	-2.3	-4.3	-6.7	0	27.0	112.0	139.0	0.0
1	165	5.2	20.1	7.4	-1.2	6.2	11	22.0	123.2	145.2	0.0
1	167	5.2	5.2	-0.1	2.3	2.2	3	6.1	141.3	147.4	0.0
2	145	21.2	21.2	0.0	0.0	0.0	4	22.6	195.8	218.4	0.0
2	146	24.0	22.6	-1.1	-2.4	-3.5	5	23.1	191.8	214.9	0.0
2	148	5.2	14.6	1.6	-7.9	-6.3	9	16.0	192.5	208.6	0.0
2	150	19.3	12.2	-0.9	-4.2	-5.0	3	12.6	190.9	203.5	0.0
2	151	20.7	20.0	-1.5	-7.3	-8.7	0	19.7	175.1	194.8	0.0
2	153	29.2	24.9	-1.4	-5.9	-7.3	0	23.5	164.0	187.5	0.0
2	155	30.0	29.6	-1.2	-10.8	-12.1	2	27.0	148.5	175.5	0.0
2	157	5.2	17.6	1.3	-7.9	-6.6	5	17.0	151.9	168.8	0.0
2	159	18.6	11.9	-1.1	1.4	0.3	0	10.4	158.7	169.1	0.0
2	161	25.2	21.9	-1.5	-2.6	-4.1	0	18.2	146.9	165.0	0.0
2	163	27.9	26.5	-1.1	-2.8	-3.9	0	21.2	139.9	161.1	0.0
2	165	5.2	16.5	5.4	-0.8	4.6	10	18.1	147.6	165.7	0.0
2	167	13.9	9.5	-0.4	3.5	3.1	4	10.3	158.5	168.8	0.0
3	145	22.5	22.5	0.0	0.0	0.0	3	24.9	188.7	213.6	0.0
3	146	25.5	24.0	-1.3	-2.5	-3.7	3	25.5	184.4	209.9	0.0
3	148	5.2	15.3	5.3	-7.0	-1.7	11	20.9	187.3	208.2	0.0

3	150	24.5	14.8	-4.2	-1.4	-5.5	2	16.1	186.7	202.7	0.0
3	151	22.8	23.6	-2.1	-6.5	-8.6	0	24.5	169.6	194.1	0.0
3	153	24.7	23.7	-1.4	-7.0	-8.4	0	23.3	162.4	185.7	0.0
3	155	20.7	22.7	-0.4	-11.6	-11.9	2	21.8	152.0	173.8	0.0
3	157	14.4	17.5	1.8	-7.8	-6.0	7	18.4	149.3	167.8	0.0
3	159	22.3	18.3	-1.3	1.1	-0.2	0	18.0	149.6	167.6	0.0
3	161	24.7	23.5	-1.8	-1.8	-3.7	0	21.5	142.4	163.9	0.0
3	163	24.8	24.7	-1.4	-4.6	-5.9	0	21.4	136.6	158.0	0.0
3	165	24.9	24.8	11.7	10.2	21.9	22	33.2	146.7	179.9	0.0
3	167	24.7	24.8	-4.8	9.2	4.4	5	28.4	155.9	184.3	0.0
4	145	36.2	36.2	0.0	0.0	0.0	4	41.0	149.0	190.1	0.0
4	146	43.9	40.0	-1.7	-1.5	-3.1	4	44.0	143.0	186.9	0.0
4	148	5.2	24.5	5.6	-5.4	0.1	10	31.6	155.5	187.1	0.0
4	150	41.1	23.1	-3.7	0.2	-3.4	3	26.2	157.4	183.6	0.0
4	151	38.7	39.9	-3.8	-2.3	-6.0	0	42.4	135.2	177.6	0.0
4	153	45.0	41.9	-3.5	-0.4	-3.9	0	41.1	132.7	173.7	0.0
4	155	45.0	45.0	-2.6	-6.9	-9.6	2	41.9	122.2	164.2	0.0
4	157	5.2	25.1	2.1	-6.6	-4.5	6	25.0	134.7	159.7	0.0
4	159	43.2	24.2	-2.4	0.1	-2.3	0	21.7	135.7	157.4	0.0
4	161	45.0	44.1	-2.9	-2.3	-5.2	0	36.9	115.3	152.1	0.0
4	163	45.0	45.0	-2.8	-3.7	-6.5	0	34.9	110.8	145.6	0.0
4	165	5.2	25.1	9.9	-1.6	8.2	14	28.2	125.7	153.9	0.0
4	167	5.2	5.2	-0.3	4.1	3.8	5	6.2	151.5	157.7	0.0
5	145	30.4	30.4	0.0	0.0	0.0	4	34.6	162.2	196.8	0.0
5	146	26.7	28.5	-1.2	-3.9	-5.1	3	31.0	160.7	191.7	0.0
5	148	20.5	23.6	4.4	-8.1	-3.7	9	29.3	158.6	187.9	0.0
5	150	30.1	25.3	-3.0	-4.2	-7.2	2	28.4	152.3	180.7	0.0
5	151	28.5	29.3	-1.6	-5.4	-7.0	0	31.9	141.8	173.7	0.0
5	153	29.1	28.8	-1.0	-6.1	-7.1	0	30.2	136.3	166.6	0.0
5	155	27.7	28.4	-1.4	-8.8	-10.2	2	28.4	128.1	156.4	0.0
5	157	20.2	23.9	1.8	-6.2	-4.4	6	25.2	126.7	152.0	0.0
5	159	26.4	23.3	-1.6	0.0	-1.7	0	23.0	127.4	150.3	0.0
5	161	26.5	26.4	-1.3	-2.2	-3.5	0	25.0	121.8	146.8	0.0

5	163	27.2	26.8	-1.4	-4.2	-5.5	0	24.1	117.2	141.3	0.0
5	165	27.5	27.3	14.2	14.9	29.1	16	38.8	131.6	170.4	0.0
5	167	28.8	28.1	-6.3	5.0	-1.3	4	33.7	135.4	169.1	0.0

Appendix Table H. SSA OJP IFC 2 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	202	30.9	30.9	0.0	0.0	0.0	0	31.9	143.2	175.1	0.0
1	204	34.3	32.6	-3.6	-16.0	-19.6	0	30.1	125.4	155.5	0.0
1	206	31.3	32.8	-2.2	-7.3	-9.5	0	28.1	117.9	146.0	0.0
1	208	34.1	32.7	-1.2	-0.7	-1.9	0	26.8	117.3	144.2	0.0
1	210	33.5	33.8	-0.5	-3.3	-3.8	4	27.3	113.1	140.4	0.0
1	212	36.3	34.9	-3.2	-4.4	-7.6	0	25.1	107.6	132.8	0.0
1	214	40.0	38.2	-1.3	-3.8	-5.1	0	26.6	101.1	127.7	0.0
1	216	37.1	38.6	-0.5	1.8	1.3	0	26.4	102.6	129.0	0.0
1	218	38.7	37.9	-0.9	-2.2	-3.1	1	25.0	100.9	125.9	0.0
1	221	39.2	39.0	-2.7	-5.0	-7.8	0	23.2	95.0	118.2	0.0
1	224	40.0	39.6	0.2	-1.3	-1.1	3	23.8	93.2	117.0	0.0
1	227	40.0	40.0	-0.9	1.2	0.3	0	23.3	94.1	117.4	0.0
1	231	40.0	40.0	1.6	-1.1	0.4	4	24.9	93.0	117.8	0.0
2	202	33.2	33.2	0.0	0.0	0.0	0	32.8	158.8	191.6	0.0
2	204	34.2	33.7	-3.0	-14.5	-17.5	2	30.3	143.8	174.1	0.0
2	206	33.9	34.0	-2.2	-6.8	-9.0	0	28.4	136.8	165.2	0.0
2	208	34.9	34.4	-1.8	0.2	-1.6	0	27.0	136.6	163.6	0.0
2	210	34.0	34.4	0.4	-1.9	-1.5	4	27.4	134.7	162.1	0.0
2	212	40.0	37.0	-3.0	-3.7	-6.7	0	26.7	128.8	155.4	0.0
2	214	36.3	38.2	-0.8	-1.7	-2.6	0	26.7	126.1	152.8	0.0
2	216	37.5	36.9	-0.6	-0.4	-0.9	0	25.2	126.7	151.9	0.0
2	218	36.8	37.2	-1.6	-1.4	-3.0	1	23.8	125.2	148.9	0.0
2	221	40.0	38.4	-1.5	-3.4	-4.9	0	23.3	120.7	144.0	0.0
2	224	40.0	40.0	0.5	-2.3	-1.8	0	25.0	117.2	142.2	0.0
2	227	40.0	40.0	-0.8	2.3	1.5	0	24.3	119.4	143.7	0.0
2	231	40.0	40.0	0.4	-2.6	-2.2	4	24.7	116.8	141.5	0.0
3	202	25.2	25.2	0.0	0.0	0.0	0	25.6	153.6	179.1	0.0
3	204	24.7	24.9	-1.7	-11.2	-12.9	1	23.5	142.7	166.2	0.0
3	206	25.7	25.2	-1.9	-6.0	-7.9	0	22.0	136.4	158.3	0.0

3	208	40.0	32.8	-1.1	0.3	-0.8	0	27.9	129.6	157.5	0.0
3	210	29.9	34.9	0.3	-1.7	-1.4	2	30.2	126.0	156.1	0.0
3	212	40.0	34.9	-2.3	-2.7	-4.9	0	27.9	123.3	151.2	0.0
3	214	30.3	35.1	-0.8	-0.8	-1.5	0	27.3	122.4	149.7	0.0
3	216	40.0	35.1	-1.8	-0.4	-2.1	0	25.5	122.0	147.5	0.0
3	218	35.7	37.9	-0.7	-1.6	-2.3	0	27.1	118.1	145.2	0.0
3	221	40.0	37.9	-2.9	-2.1	-5.0	0	24.2	116.0	140.2	0.0
3	224	37.5	38.8	0.3	-2.2	-2.0	2	25.3	113.0	138.2	0.0
3	227	40.0	38.8	-0.3	2.1	1.8	0	25.0	115.1	140.1	0.0
3	231	40.0	40.0	-1.4	-0.8	-2.3	1	24.5	113.3	137.8	0.0
4	202	13.2	13.2	0.0	0.0	0.0	0	13.2	155.2	168.4	0.0
4	204	40.0	26.6	-2.9	-10.5	-13.4	2	23.5	131.5	154.9	0.0
4	206	40.0	40.0	-3.1	-7.0	-10.1	0	32.2	112.7	144.9	0.0
4	208	40.0	40.0	-2.5	1.3	-1.3	0	29.6	114.0	143.6	0.0
4	210	40.0	40.0	0.8	-2.5	-1.7	5	30.4	111.5	141.9	0.0
4	212	36.6	38.3	-3.1	-3.8	-6.9	0	25.9	109.1	135.0	0.0
4	214	40.0	38.3	-1.2	-0.6	-1.8	0	24.8	108.5	133.2	0.0
4	216	40.0	40.0	-1.0	-0.1	-1.1	0	25.1	107.0	132.2	0.0
4	218	40.0	40.0	-1.1	-1.7	-2.7	1	24.1	105.4	129.4	0.0
4	221	40.0	40.0	-2.4	-2.2	-4.6	0	21.7	103.1	124.8	0.0
4	224	40.0	40.0	1.1	-1.9	-0.8	4	22.8	101.2	124.0	0.0
4	227	40.0	40.0	-1.2	2.0	0.8	0	21.7	103.2	124.9	0.0
4	231	40.0	40.0	0.7	-0.7	0.1	4	22.4	102.6	124.9	0.0
5	202	28.1	28.1	0.0	0.0	0.0	1	31.0	136.8	167.8	0.0
5	204	35.5	31.8	-3.6	-9.9	-13.5	0	31.6	122.7	154.3	0.0
5	206	31.2	33.3	-1.6	-5.9	-7.5	0	31.6	115.2	146.8	0.0
5	208	27.2	29.2	-1.6	-2.1	-3.6	0	25.8	117.3	143.1	0.0
5	210	32.2	29.7	-0.2	-0.5	-0.7	6	26.1	116.3	142.4	0.0
5	212	31.6	31.9	-2.7	-4.9	-7.7	0	25.5	109.2	134.8	0.0
5	214	34.5	33.0	-1.7	-0.2	-1.9	0	24.8	108.0	132.8	0.0
5	216	40.0	37.3	-0.9	-1.0	-1.9	0	27.6	103.3	130.9	0.0
5	218	34.4	37.2	-1.4	-1.5	-2.9	1	26.2	101.9	128.1	0.0
5	221	40.0	37.2	-2.9	-4.6	-7.5	0	23.3	97.3	120.6	0.0

5	224	38.8	39.4	-0.9	-2.2	-3.0	4	24.1	93.5	117.6	0.0
5	227	37.6	38.2	-0.5	1.6	1.1	0	22.7	95.9	118.6	0.0
5	231	40.0	38.8	-0.2	-0.8	-1.0	3	22.9	94.7	117.6	0.0

Appendix Table I. SSA OJP IFC 3 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	242	28.6	28.6	0.0	0.0	0.0	0	10.8	99.6	110.3	0.0
1	244	28.7	28.7	-0.4	-0.6	-1.0	0	10.4	99.0	109.3	0.0
1	246	28.6	28.7	-0.3	-2.4	-2.7	0	10.1	96.6	106.6	0.0
1	249	15.2	21.9	3.1	-2.6	0.5	12	9.3	97.8	107.1	0.0
1	251	15.2	15.2	-0.6	-0.6	-1.2	0	4.5	101.4	105.9	0.0
1	254	15.2	15.2	-0.4	1.4	1.0	0	4.1	102.8	106.9	0.0
1	256	28.6	21.9	-0.6	-0.8	-1.4	0	7.3	98.3	105.5	0.0
1	258	28.6	28.6	-0.6	-0.5	-1.0	0	10.9	93.7	104.5	0.0
1	261	28.6	28.6	-0.3	-1.0	-1.2	0	10.6	92.7	103.3	0.0
2	242	28.8	28.8	0.0	0.0	0.0	2	11.3	125.3	136.6	0.0
2	244	28.8	28.8	-0.2	0.1	-0.1	0	11.1	125.4	136.5	0.0
2	246	28.8	28.8	-0.6	-2.1	-2.7	0	10.5	123.3	133.8	0.0
2	249	28.9	28.9	5.2	-3.8	1.4	20	15.7	119.5	135.2	0.0
2	251	28.8	28.9	-1.3	-0.1	-1.4	0	14.5	119.4	133.9	0.0
2	254	28.7	28.8	-0.7	2.5	1.7	0	13.7	121.9	135.6	0.0
2	256	28.8	28.8	-0.5	-0.2	-0.7	0	13.2	121.7	134.9	0.0
2	258	28.8	28.8	-0.5	-1.2	-1.7	0	12.8	120.5	133.2	0.0
2	261	28.8	28.8	-0.9	-1.5	-2.4	0	11.8	119.0	130.9	0.0
3	242	28.7	28.7	0.0	0.0	0.0	2	11.5	121.3	132.8	0.0
3	244	28.8	28.8	-0.4	-0.2	-0.6	0	11.1	121.1	132.2	0.0
3	246	28.8	28.8	-0.4	-2.0	-2.4	0	10.8	119.0	129.8	0.0
3	249	45.0	36.9	7.8	-2.9	4.9	13	24.3	110.4	134.7	0.0
3	251	29.1	37.1	-1.2	0.1	-1.1	0	23.1	110.5	133.6	0.0
3	254	15.2	22.2	-0.4	2.4	2.0	0	10.5	125.1	135.6	0.0
3	256	29.0	22.1	-0.3	-0.8	-1.1	0	10.1	124.4	134.5	0.0
3	258	28.8	28.9	-0.9	-0.6	-1.5	0	14.8	118.2	133.0	0.0
3	261	28.8	28.8	-1.0	-1.4	-2.4	0	13.7	117.0	130.6	0.0
4	242	28.6	28.6	0.0	0.0	0.0	3	10.1	109.5	119.6	0.0
4	244	28.7	28.7	-0.6	-0.6	-1.2	0	9.4	108.9	118.4	0.0

4	246	28.7	28.7	-0.1	-1.6	-1.7	0	9.4	107.3	116.7	0.0
4	249	29.5	29.1	7.2	-2.3	4.9	15	16.7	104.8	121.5	0.0
4	251	28.7	29.1	-1.8	0.6	-1.2	0	15.0	105.3	120.3	0.0
4	254	28.6	28.7	-0.8	1.9	1.1	0	13.8	107.6	121.4	0.0
4	256	28.6	28.6	-1.0	-1.9	-2.8	0	12.8	105.8	118.6	0.0
4	258	28.6	28.6	-0.8	-0.3	-1.1	0	12.0	105.5	117.5	0.0
4	261	28.6	28.6	-0.7	-0.9	-1.6	0	11.4	104.6	115.9	0.0
5	242	28.7	28.7	0.0	0.0	0.0	2	10.7	99.6	110.3	0.0
5	244	28.8	28.8	-0.3	-0.8	-1.1	0	10.5	98.8	109.2	0.0
5	246	28.7	28.8	-0.3	-1.8	-2.1	0	10.2	97.0	107.1	0.0
5	249	45.0	36.9	5.1	-3.2	1.9	12	20.4	88.6	109.0	0.0
5	251	29.2	37.1	-1.4	-0.7	-2.1	0	19.2	87.8	107.0	0.0
5	254	28.7	29.0	-0.5	2.1	1.6	0	13.4	95.2	108.5	0.0
5	256	28.8	28.8	-0.6	-0.7	-1.3	0	12.7	94.6	107.3	0.0
5	258	28.9	28.9	-0.4	-0.8	-1.3	0	12.3	93.7	106.0	0.0
5	261	28.8	28.9	-0.7	-0.9	-1.6	0	11.6	92.8	104.4	0.0

Appendix Table J. SSA YJP IFC 2 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	202	40.0	40.0	0.0	0.0	0.0	0	45.0	54.1	99.1	0.0
1	204	40.0	40.0	-3.6	-3.9	-7.5	2	41.4	50.1	91.5	0.0
1	206	37.8	38.9	-4.9	-2.6	-7.5	0	35.4	48.6	84.0	0.0
1	208	15.0	26.4	-4.0	-1.3	-5.2	0	20.3	58.5	78.8	0.0
1	210	16.0	15.5	-0.1	-2.7	-2.8	7	11.7	64.4	76.0	0.0
1	212	14.2	15.1	-1.9	-3.9	-5.8	0	9.5	60.8	70.2	0.0
1	215	13.4	13.8	-1.0	-1.9	-2.9	0	7.7	59.7	67.3	0.0
1	216	12.7	13.1	-0.3	-2.1	-2.4	0	7.0	58.0	64.9	0.0
1	218	12.7	12.7	-0.4	-1.7	-2.0	0	6.4	56.5	62.9	0.0
1	221	10.9	11.8	-0.8	-3.8	-4.5	0	5.2	53.2	58.4	0.0
1	224	5.2	8.1	-0.1	-1.7	-1.9	2	3.3	53.3	56.5	0.0
1	227	5.2	5.2	0.0	-0.3	-0.3	0	1.9	54.2	56.2	0.0
1	231	14.2	9.7	0.4	-1.1	-0.7	2	4.4	51.1	55.5	0.0
2	202	40.0	40.0	0.0	0.0	0.0	0	39.5	48.2	87.6	0.0
2	204	40.0	40.0	-3.3	-3.2	-6.6	3	36.1	44.9	81.0	0.0
2	206	37.9	39.0	-4.6	-1.4	-6.0	0	30.7	44.3	75.0	0.0
2	208	5.2	21.6	-3.2	-1.0	-4.1	0	13.9	57.0	70.9	0.0
2	210	15.3	10.3	0.6	-0.9	-0.3	8	6.8	63.8	70.6	0.0
2	212	11.5	13.4	-1.4	-2.7	-4.1	0	7.7	58.8	66.5	0.0
2	215	5.2	8.4	-0.1	-0.3	-0.4	0	4.4	61.7	66.1	0.0
2	216	5.2	5.2	-0.1	-1.3	-1.5	0	2.4	62.3	64.7	0.0
2	218	9.8	7.5	-0.1	-2.0	-2.1	0	3.6	59.0	62.5	0.0
2	221	5.2	7.5	-0.4	-3.5	-3.9	0	3.2	55.5	58.6	0.0
2	224	5.2	5.2	-0.1	-2.0	-2.1	4	2.0	54.6	56.5	0.0
2	227	5.2	5.2	0.0	3.6	3.5	0	1.9	58.1	60.1	0.0
2	231	11.8	8.5	0.4	-3.1	-2.8	4	3.9	53.4	57.3	0.0
3	202	40.0	40.0	0.0	0.0	0.0	0	39.7	50.8	90.5	0.0
3	204	40.0	40.0	-3.7	-4.4	-8.1	3	35.9	46.5	82.4	0.0
3	206	5.2	22.6	-3.6	-3.6	-7.2	0	16.8	58.3	75.2	0.0

3	208	5.2	5.2	-0.6	-2.8	-3.3	0	2.6	69.3	71.8	0.0
3	210	14.6	9.9	1.0	-0.9	0.1	6	6.5	65.4	71.9	0.0
3	212	5.2	9.9	-1.3	-2.9	-4.2	0	5.2	62.5	67.7	0.0
3	215	5.2	5.2	-0.2	-1.3	-1.5	0	2.2	64.0	66.2	0.0
3	216	5.2	5.2	-0.1	-0.8	-0.9	0	2.1	63.2	65.3	0.0
3	218	5.2	5.2	-0.1	-2.5	-2.6	0	2.0	60.7	62.7	0.0
3	221	5.2	5.2	-0.3	-2.7	-3.0	0	1.7	58.0	59.7	0.0
3	224	5.2	5.2	0.2	-0.8	-0.6	3	1.9	57.1	59.1	0.0
3	227	5.2	5.2	-0.2	0.4	0.2	0	1.8	57.5	59.3	0.0
3	231	5.2	5.2	0.3	-0.8	-0.5	2	2.0	56.7	58.7	0.0
4	202	40.0	40.0	0.0	0.0	0.0	0	40.1	47.3	87.4	0.0
4	204	40.0	40.0	-3.3	-3.0	-6.3	3	36.8	44.3	81.1	0.0
4	206	40.0	40.0	-4.5	-1.6	-6.1	0	32.3	42.7	75.0	0.0
4	208	10.6	25.3	-3.0	-0.1	-3.1	0	17.3	54.6	71.9	0.0
4	210	40.0	25.3	4.4	-0.9	3.5	8	21.7	53.7	75.4	0.0
4	212	15.8	27.9	-4.3	-2.0	-6.3	0	19.5	49.6	69.1	0.0
4	215	13.3	14.6	-1.1	0.3	-0.8	0	9.0	59.3	68.3	0.0
4	216	5.2	9.3	-0.9	-2.6	-3.5	0	4.7	60.2	64.9	0.0
4	218	9.9	7.6	0.0	-2.1	-2.1	0	3.6	59.1	62.8	0.0
4	221	5.2	7.6	-0.6	0.2	-0.4	0	3.0	59.3	62.4	0.0
4	224	15.5	10.4	1.6	-4.0	-2.4	5	6.0	53.9	59.9	0.0
4	227	5.2	10.4	-1.4	0.2	-1.2	0	4.6	54.1	58.7	0.0
4	231	18.1	11.7	1.7	-0.4	1.3	4	6.9	53.1	60.0	0.0
5	202	40.0	40.0	0.0	0.0	0.0	0	35.7	48.1	83.8	0.0
5	204	40.0	40.0	-3.0	-3.2	-6.3	2	32.6	44.9	77.5	0.0
5	206	5.2	22.6	-2.9	-2.9	-5.7	0	15.6	56.2	71.8	0.0
5	208	5.2	5.2	-0.4	-1.7	-2.1	0	2.3	67.5	69.7	0.0
5	210	5.2	5.2	-0.1	-2.0	-2.1	7	2.2	65.5	67.7	0.0
5	212	5.2	5.2	-0.2	-2.5	-2.7	0	1.9	63.0	64.9	0.0
5	215	5.2	5.2	-0.3	-1.8	-2.1	0	1.6	61.2	62.9	0.0
5	216	5.2	5.2	0.0	-0.3	-0.3	0	1.6	61.0	62.6	0.0
5	218	5.2	5.2	0.0	-1.6	-1.6	0	1.6	59.4	61.0	0.0
5	221	5.2	5.2	-0.4	-2.1	-2.5	0	1.2	57.3	58.5	0.0

5	224	5.2	5.2	0.2	-1.4	-1.2	4	1.4	55.9	57.3	0.0
5	227	5.2	5.2	0.0	0.5	0.4	0	1.4	56.4	57.8	0.0
5	231	5.2	5.2	0.1	0.1	0.1	4	1.4	56.5	57.9	0.0

Appendix Table K. SSA YJP IFC 3 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta SM Below (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	242	11.1	11.1	0.0	0.0	0.0	1	4.7	48.0	52.7	0.0
1	244	5.1	8.1	-0.3	-1.5	-1.8	0	3.2	47.8	51.0	0.0
1	246	11.8	8.5	0.2	-0.8	-0.7	0	3.5	46.8	50.3	0.0
1	249	50.5	31.2	8.0	-0.1	7.9	13	21.6	36.6	58.2	0.0
1	251	85.0	67.8	-2.2	-0.2	-2.4	0	40.0	15.8	55.8	0.0
1	254	52.8	68.9	-1.6	0.3	-1.3	0	39.1	15.4	54.5	0.0
1	256	5.1	29.0	-1.4	-0.8	-2.3	0	14.8	37.5	52.2	0.0
1	258	12.9	9.0	-0.1	-0.9	-1.1	0	4.2	47.0	51.2	0.0
1	261	5.1	9.0	-0.7	-1.7	-2.4	0	3.5	45.3	48.8	0.0
2	242	5.1	5.1	0.0	0.0	0.0	3	2.3	51.8	54.0	0.0
2	244	5.1	5.1	-0.1	-0.4	-0.6	0	2.2	51.3	53.5	0.0
2	246	5.1	5.1	0.0	-1.5	-1.5	0	2.2	49.8	52.0	0.0
2	249	13.0	9.1	0.5	1.1	1.5	18	4.4	49.1	53.5	0.0
2	251	5.1	9.1	-0.4	-0.5	-0.9	0	3.9	48.7	52.6	0.0
2	254	5.1	5.1	0.0	0.3	0.3	0	2.2	50.8	53.0	0.0
2	256	5.1	5.1	-0.1	-0.8	-0.9	0	2.1	50.0	52.1	0.0
2	258	5.1	5.1	0.1	-1.2	-1.1	0	2.2	48.8	51.0	0.0
2	261	5.1	5.1	-0.1	-1.1	-1.2	0	2.1	47.7	49.8	0.0
3	242	5.1	5.1	0.0	0.0	0.0	1	1.8	53.9	55.7	0.0
3	244	5.1	5.1	0.0	-0.6	-0.6	0	1.8	53.3	55.1	0.0
3	246	5.1	5.1	0.1	-1.5	-1.4	0	1.9	51.9	53.7	0.0
3	249	54.8	30.0	7.0	-0.8	6.2	11	20.1	39.8	59.9	0.0
3	251	56.8	55.8	-2.0	-0.4	-2.4	0	33.3	24.2	57.5	0.0
3	254	5.1	31.0	-1.9	0.1	-1.8	0	16.8	39.0	55.7	0.0
3	256	5.1	5.1	-0.4	-2.1	-2.5	0	2.0	51.3	53.3	0.0
3	258	5.1	5.1	-0.1	-0.6	-0.7	0	2.0	50.6	52.6	0.0
3	261	5.1	5.1	-0.1	-1.3	-1.4	0	1.8	49.4	51.2	0.0
4	242	5.1	5.1	0.0	0.0	0.0	2	2.2	52.5	54.8	0.0
4	244	5.1	5.1	-0.2	-0.9	-1.1	0	2.1	51.7	53.7	0.0

4	246	5.1	5.1	-0.1	-1.3	-1.3	0	2.0	50.4	52.4	0.0
4	249	60.0	32.6	12.7	1.4	14.1	19	27.6	38.9	66.5	0.0
4	251	62.2	61.1	-3.5	-0.2	-3.7	0	42.2	20.6	62.8	0.0
4	254	60.7	61.5	-2.0	0.3	-1.7	0	40.4	20.7	61.1	0.0
4	256	5.1	32.9	-2.0	-0.7	-2.7	0	20.3	38.1	58.4	0.0
4	258	5.1	5.1	-0.2	-1.6	-1.8	0	2.4	54.1	56.6	0.0
4	261	5.1	5.1	-0.4	-2.4	-2.8	0	2.0	51.8	53.8	0.0
5	242	5.1	5.1	0.0	0.0	0.0	2	1.2	54.1	55.3	0.0
5	244	5.1	5.1	-0.1	-0.5	-0.6	0	1.1	53.6	54.7	0.0
5	246	5.1	5.1	-0.1	-0.8	-0.9	0	1.0	52.8	53.9	0.0
5	249	5.1	5.1	0.5	0.5	1.0	18	1.5	53.3	54.8	0.0
5	251	5.1	5.1	0.0	0.0	0.0	0	1.6	53.3	54.8	0.0
5	254	5.1	5.1	-0.1	0.5	0.4	0	1.4	53.8	55.2	0.0
5	256	5.1	5.1	-0.2	-0.8	-1.0	0	1.2	53.0	54.2	0.0
5	258	5.1	5.1	0.0	-0.9	-0.8	0	1.3	52.1	53.4	0.0
5	261	5.1	5.1	-0.3	-0.6	-0.9	0	1.0	51.5	52.5	0.0
6	242	5.1	5.1	0.0	0.0	0.0	2	2.0	56.6	58.6	0.0
6	244	5.1	5.1	-0.5	-1.8	-2.3	0	1.6	54.8	56.3	0.0
6	246	5.1	5.1	-0.2	-1.0	-1.2	0	1.3	53.8	55.1	0.0
6	249	5.1	5.1	0.0	-2.5	-2.6	16	1.3	51.2	52.5	0.0
6	251	5.1	5.1	-0.1	-3.0	-3.1	0	1.2	48.2	49.5	0.0
6	254	5.1	5.1	-0.1	-0.8	-0.9	0	1.1	47.5	48.6	0.0
6	256	5.1	5.1	0.0	-1.2	-1.2	0	1.1	46.3	47.4	0.0
6	258	5.1	5.1	1.7	16.4	18.2	0	2.8	62.7	65.5	0.0
6	261	5.1	5.1	-0.4	-3.5	-3.9	0	2.4	59.2	61.6	0.0

Appendix Table L. NSA OJP IFC 1 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	150	28.8	28.8	0.0	0.0	0.0	0	18.5	125.6	144.0	0.0
1	152	28.8	28.8	-0.3	-5.8	-6.1	0	18.2	119.8	138.0	0.0
1	154	28.7	28.8	0.1	-3.9	-3.8	0	18.2	116.0	134.2	0.0
1	156	28.8	28.8	-2.6	-6.0	-8.6	0	15.5	110.0	125.5	0.0
1	158	28.8	28.8	-0.3	-3.6	-3.9	0	15.3	106.3	121.6	0.0
1	160	28.8	28.8	-1.7	-2.7	-4.3	0	13.7	103.6	117.3	0.0
1	162	28.8	28.8	-1.5	-3.9	-5.4	0	12.2	99.7	111.9	0.0
1	164	28.8	28.8	-0.1	-3.2	-3.3	0	12.2	96.5	108.6	0.0
1	166	15.2	22.0	12.2	24.2	36.4	48	19.6	125.4	145.0	0.0
2	150	29.1	29.1	0.0	0.0	0.0	0	21.7	125.4	147.1	0.0
2	152	29.5	29.3	0.6	-7.5	-7.0	0	22.5	117.7	140.1	0.0
2	154	29.1	29.3	-1.4	-8.5	-9.8	0	21.1	109.2	130.3	0.0
2	156	28.9	29.0	-0.1	-6.1	-6.2	0	20.7	103.4	124.1	0.0
2	158	28.9	28.9	-2.0	-8.8	-10.9	0	18.5	94.7	113.2	0.0
2	160	28.8	28.9	-0.6	-2.1	-2.7	0	17.9	92.7	110.6	0.0
2	162	28.8	28.8	0.4	-2.5	-2.1	0	18.3	90.2	108.5	0.0
2	164	28.8	28.8	-1.2	-2.9	-4.1	0	17.1	87.3	104.5	0.0
2	166	45.0	36.9	17.7	7.5	25.2	22	41.7	88.0	129.6	0.0
3	150	28.7	28.7	0.0	0.0	0.0	0	18.2	131.4	149.6	0.0
3	152	28.8	28.8	0.3	-4.9	-4.5	0	18.5	126.6	145.1	0.0
3	154	28.7	28.8	-1.1	-5.4	-6.6	0	17.4	121.1	138.5	0.0
3	156	15.2	22.0	-0.2	-4.3	-4.5	0	11.3	122.7	134.0	0.0
3	158	28.8	22.0	-2.3	-8.4	-10.7	0	9.1	114.3	123.3	0.0
3	160	28.7	28.8	0.1	-2.8	-2.7	0	14.6	106.0	120.6	0.0
3	162	28.8	28.8	-1.6	-6.2	-7.8	0	13.0	99.8	112.8	0.0
3	164	28.8	28.8	-0.2	-4.4	-4.6	0	12.9	95.4	108.2	0.0
3	166	15.2	22.0	8.7	18.7	27.4	27	16.7	118.9	135.6	0.0
4	150	28.6	28.6	0.0	0.0	0.0	0	18.4	129.9	148.3	0.0
4	152	15.2	21.9	0.2	-2.3	-2.1	0	12.2	134.0	146.2	0.0

4	154	28.7	22.0	-0.6	-4.4	-5.0	0	11.5	129.7	141.2	0.0
4	156	28.6	28.7	-0.1	-3.4	-3.4	0	17.7	120.1	137.8	0.0
4	158	28.8	28.7	-2.0	-7.4	-9.4	0	15.9	112.5	128.4	0.0
4	160	28.7	28.8	-0.8	0.0	-0.7	0	15.1	112.6	127.7	0.0
4	162	28.8	28.8	-0.8	-5.0	-5.8	0	14.3	107.6	121.9	0.0
4	164	28.7	28.8	0.8	-7.8	-7.1	0	15.1	99.7	114.8	0.0
4	166	15.2	22.0	6.7	18.1	24.8	34	16.6	123.0	139.6	0.0
5	150	29.2	29.2	0.0	0.0	0.0	0	23.4	139.9	163.3	0.0
5	152	45.0	37.1	0.5	-5.0	-4.6	0	32.2	126.5	158.8	0.0
5	154	29.1	37.1	-1.1	-6.0	-7.1	0	31.0	120.6	151.6	0.0
5	156	29.2	29.2	-0.8	-6.2	-7.0	0	22.1	122.5	144.6	0.0
5	158	28.9	29.1	-2.1	-5.8	-7.9	0	19.9	116.8	136.7	0.0
5	160	28.9	28.9	0.3	1.0	1.3	0	20.1	117.9	138.0	0.0
5	162	28.9	28.9	-1.9	-8.6	-10.5	0	18.3	109.2	127.5	0.0
5	164	28.9	28.9	0.0	-4.9	-4.9	0	18.3	104.4	122.6	0.0
5	166	45.0	37.0	18.1	10.2	28.3	29	43.5	107.4	150.9	0.0

Appendix Table M. NSA OJP IFC 2 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
1	201	65.0	65.0	0.0	0.0	0.0	21	58.1	71.2	129.3	0.0
1	203	65.0	65.0	-5.0	-3.0	-8.0	0	53.1	68.1	121.3	0.0
1	205	65.0	65.0	-2.6	-0.9	-3.5	0	50.6	67.2	117.8	0.0
1	207	20.1	42.5	-2.8	-0.5	-3.2	0	29.5	85.0	114.6	0.0
1	209	20.1	20.1	0.0	-1.8	-1.7	0	11.3	101.5	112.8	0.0
1	211	20.1	20.1	-1.5	-2.8	-4.2	0	9.8	98.7	108.6	0.0
1	213	20.1	20.1	0.1	-1.2	-1.1	0	10.0	97.5	107.5	0.0
1	215	20.1	20.1	-0.2	-1.9	-2.2	0	9.7	95.6	105.3	0.0
1	217	20.1	20.1	-0.4	-1.0	-1.4	0	9.3	94.6	103.9	0.0
1	219	65.0	42.5	11.5	1.8	13.3	26	35.3	81.9	117.2	0.0
2	201	65.0	65.0	0.0	0.0	0.0	10	65.4	55.8	121.2	0.0
2	203	65.0	65.0	-3.5	-0.2	-3.7	0	61.9	55.6	117.5	0.0
2	205	65.0	65.0	-4.0	-0.7	-4.7	0	57.9	54.9	112.8	0.0
2	207	65.0	65.0	-2.9	-0.4	-3.3	0	55.0	54.5	109.4	0.0
2	209	65.0	65.0	-1.4	-0.9	-2.3	0	53.6	53.5	107.1	0.0
2	211	65.0	65.0	-2.0	-1.6	-3.6	0	51.6	51.9	103.5	0.0
2	213	20.1	42.5	-0.5	-0.7	-1.2	0	32.8	69.6	102.3	0.0
2	215	20.1	20.1	-0.4	-2.3	-2.7	0	14.3	85.4	99.6	0.0
2	217	20.1	20.1	-0.9	-1.8	-2.6	0	13.4	83.6	97.0	0.0
2	219	65.0	42.5	9.3	0.9	10.2	10	39.5	67.7	107.2	0.0
3	201	65.0	65.0	0.0	0.0	0.0	18	61.1	70.8	131.9	0.0
3	203	65.0	65.0	-5.6	-2.9	-8.5	0	55.5	67.8	123.3	0.0
3	205	20.1	42.5	-3.5	-1.8	-5.3	0	31.9	86.2	118.1	0.0
3	207	20.1	20.1	-0.6	-2.1	-2.7	0	11.4	104.0	115.4	0.0
3	209	20.1	20.1	-0.4	-3.0	-3.4	0	11.0	101.0	112.0	0.0
3	211	20.1	20.1	-0.1	-3.4	-3.6	0	10.8	97.6	108.4	0.0
3	213	26.5	23.3	2.6	-2.4	0.2	0	15.6	92.9	108.6	0.0
3	215	20.1	23.3	-3.3	-2.6	-5.9	0	12.4	90.4	102.7	0.0
3	217	20.1	20.1	-0.2	-1.3	-1.6	0	10.1	91.1	101.2	0.0

3	219	65.0	42.5	4.7	-1.7	3.1	12	29.8	74.5	104.2	0.0
4	201	65.0	65.0	0.0	0.0	0.0	13	56.7	69.8	126.5	0.0
4	203	64.3	64.7	-3.3	0.8	-2.5	0	53.2	70.8	124.0	0.0
4	205	20.1	42.2	-0.9	-0.9	-1.8	0	33.4	88.8	122.2	0.0
4	207	20.1	20.1	-0.5	-1.4	-2.0	0	12.5	107.8	120.2	0.0
4	209	20.1	20.1	-0.1	-2.1	-2.2	0	12.4	105.7	118.0	0.0
4	211	20.1	20.1	-1.6	-2.8	-4.4	0	10.7	102.9	113.6	0.0
4	213	20.1	20.1	0.6	-1.6	-1.0	0	11.3	101.3	112.7	0.0
4	215	20.1	20.1	0.0	-2.0	-2.0	0	11.4	99.3	110.7	0.0
4	217	20.1	20.1	-0.6	-1.6	-2.1	0	10.8	97.7	108.6	0.0
4	219	57.1	38.6	5.2	2.5	7.8	15	29.6	86.8	116.3	0.0
5	201	57.7	57.7	0.0	0.0	0.0	19	63.7	79.9	143.6	0.0
5	203	58.2	58.0	-5.2	1.7	-3.5	0	58.7	81.4	140.1	0.0
5	205	58.6	58.4	-4.1	-0.3	-4.3	0	55.1	80.7	135.8	0.0
5	207	54.6	56.6	-0.6	-0.7	-1.2	0	52.9	81.6	134.5	0.0
5	209	55.7	55.1	-2.7	-1.4	-4.2	0	48.8	81.5	130.3	0.0
5	211	20.1	37.9	-2.5	-1.6	-4.0	0	31.0	95.3	126.3	0.0
5	213	20.1	20.1	0.4	-1.5	-1.1	0	14.4	110.8	125.2	0.0
5	215	20.1	20.1	0.2	-2.9	-2.7	0	14.6	107.9	122.5	0.0
5	217	20.1	20.1	-1.8	-0.9	-2.6	0	12.9	107.0	119.9	0.0
5	219	20.1	20.1	6.3	9.0	15.3	17	19.2	116.0	135.2	0.0

Appendix Table N. NSA YJP IFC 1 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
2	150	34.9	34.9	0.0	0.0	0.0	0	26.6	0.1	26.7	0.0
2	151	34.9	34.9	8.4	0.0	8.4	9	35.0	0.1	35.1	0.0
2	152	34.9	34.9	-0.9	0.0	-0.9	0	34.1	0.1	34.2	0.0
2	154	34.9	34.9	-5.7	0.0	-5.7	0	28.4	0.1	28.5	0.0
2	156	34.9	34.9	-0.2	0.0	-0.3	0	28.2	0.1	28.3	0.0
2	158	34.9	34.9	-4.8	0.0	-4.9	0	23.3	0.1	23.4	0.0
2	160	34.9	34.9	-0.6	0.0	-0.6	0	22.7	0.1	22.8	0.0
2	162	34.9	34.9	-2.4	0.0	-2.4	0	20.3	0.1	20.4	0.0
2	164	34.9	34.9	1.2	0.0	1.2	0	21.5	0.1	21.6	0.0
2	166	35.0	35.0	18.3	0.0	18.3	31	39.8	0.0	39.8	0.0
3	150	54.9	54.9	0.0	0.0	0.0	0	45.7	0.1	45.9	0.0
3	151	54.9	54.9	7.6	0.0	7.6	3	53.3	0.1	53.5	0.0
3	152	54.9	54.9	0.1	0.0	0.1	0	53.4	0.1	53.6	0.0
3	154	54.9	54.9	-5.9	0.0	-5.9	0	47.6	0.1	47.7	0.0
3	156	54.9	54.9	-1.5	0.0	-1.5	0	46.0	0.1	46.2	0.0
3	158	54.9	54.9	-8.3	0.0	-8.4	0	37.7	0.1	37.8	0.0
3	160	54.9	54.9	-1.6	0.0	-1.6	0	36.1	0.1	36.2	0.0
3	162	54.9	54.9	-3.7	0.0	-3.7	0	32.4	0.1	32.5	0.0
3	164	54.9	54.9	0.4	0.0	0.4	0	32.8	0.1	32.9	0.0
3	166	55.0	55.0	29.2	0.0	29.2	29	62.0	0.1	62.1	0.0
4	150	44.9	44.9	0.0	0.0	0.0	0	42.5	0.2	42.7	0.0
4	151	44.9	44.9	7.9	0.0	7.9	9	50.4	0.2	50.6	0.0
4	152	44.9	44.9	-3.5	0.0	-3.5	0	46.9	0.2	47.1	0.0
4	154	44.9	44.9	-3.7	0.0	-3.7	0	43.2	0.2	43.4	0.0
4	156	44.9	44.9	-2.1	0.0	-2.1	0	41.1	0.2	41.3	0.0
4	158	44.9	44.9	-4.2	0.0	-4.3	0	36.9	0.1	37.0	0.0
4	160	44.9	44.9	-2.1	0.0	-2.1	0	34.8	0.1	34.9	0.0
4	162	44.9	44.9	-3.2	0.0	-3.2	0	31.6	0.1	31.8	0.0
4	164	44.9	44.9	0.7	0.0	0.7	0	32.4	0.1	32.5	0.0

4	166	45.0	45.0	29.4	0.0	29.4	31	61.9	0.0	61.9	0.0
5	150	44.9	44.9	0.0	0.0	0.0	0	37.6	0.1	37.7	0.0
5	151	45.0	45.0	10.4	0.0	10.4	13	48.2	0.0	48.2	0.0
5	152	45.0	45.0	-0.3	0.0	-0.3	0	47.9	0.0	47.9	0.0
5	154	44.9	45.0	-3.9	0.0	-3.9	0	44.0	0.0	44.0	0.0
5	156	44.9	44.9	-5.4	0.0	-5.4	0	38.4	0.1	38.5	0.0
5	158	44.9	44.9	-7.3	0.0	-7.3	0	31.1	0.1	31.2	0.0
5	160	44.9	44.9	-3.4	0.0	-3.4	0	27.7	0.1	27.8	0.0
5	162	44.9	44.9	-3.1	0.0	-3.1	0	24.6	0.1	24.7	0.0
5	164	44.9	44.9	0.2	0.0	0.1	0	24.7	0.1	24.8	0.0
5	166	45.0	45.0	38.6	0.0	38.6	47	63.4	0.0	63.4	0.0
6	150	34.9	34.9	0.0	0.0	0.0	0	24.9	0.1	25.0	0.0
6	151	34.9	34.9	10.0	0.0	10.0	8	34.9	0.1	35.0	0.0
6	152	34.9	34.9	-1.7	0.0	-1.7	0	33.1	0.1	33.3	0.0
6	154	34.9	34.9	-6.4	0.0	-6.4	0	26.7	0.1	26.8	0.0
6	156	34.9	34.9	-0.3	0.0	-0.3	0	26.4	0.1	26.5	0.0
6	158	34.9	34.9	-6.5	0.0	-6.5	0	20.0	0.1	20.1	0.0
6	160	34.9	34.9	-1.8	0.0	-1.9	0	18.1	0.1	18.2	0.0
6	162	34.9	34.9	-2.2	0.0	-2.2	0	15.9	0.1	16.0	0.0
6	164	34.9	34.9	1.0	0.0	1.0	0	16.9	0.1	17.0	0.0
6	166	34.9	34.9	24.2	0.1	24.2	39	41.1	0.2	41.2	0.0
7	150	54.9	54.9	0.0	0.0	0.0	0	46.3	0.1	46.4	0.0
7	151	54.9	54.9	4.3	0.0	4.3	6	50.6	0.1	50.7	0.0
7	152	54.9	54.9	0.2	0.0	0.2	0	50.8	0.1	50.9	0.0
7	154	54.9	54.9	-6.0	0.0	-6.0	0	44.8	0.1	45.0	0.0
7	156	54.9	54.9	-3.3	0.0	-3.3	0	41.6	0.1	41.7	0.0
7	158	54.9	54.9	-6.5	0.0	-6.5	0	35.1	0.1	35.2	0.0
7	160	54.9	54.9	-2.5	0.0	-2.5	0	32.6	0.1	32.7	0.0
7	162	54.9	54.9	-2.3	0.0	-2.3	0	30.3	0.1	30.4	0.0
7	164	54.9	54.9	1.0	0.0	1.0	0	31.3	0.1	31.4	0.0
7	166	55.0	55.0	38.3	0.0	38.4	29	69.7	0.1	69.8	0.0

Appendix Table O. NSA YJP IFC 2 Soil Moisture Balance

TUBE	DOY	DOY ZFP (cm)	Mean ZFP (cm)	Delta SM Above MZFP (mm)	Delta SM Below MZFP (mm)	Delta Total SM (mm)	PPT (mm)	Total Above MZFP (mm)	Total Below MZFP (mm)	Total Profile (mm)	Balance (mm)
2	201	34.9	34.9	0.0	0.0	0.0	14	32.4	0.1	32.5	0.0
2	203	34.9	34.9	-3.4	0.0	-3.4	1	29.0	0.1	29.1	0.0
2	205	34.9	34.9	-6.5	0.0	-6.5	0	22.5	0.1	22.6	0.0
2	207	34.9	34.9	-1.5	0.0	-1.6	0	21.0	0.1	21.1	0.0
2	209	34.9	34.9	0.0	0.0	0.0	0	21.0	0.1	21.1	0.0
2	211	34.9	34.9	-2.3	0.0	-2.3	0	18.7	0.1	18.8	0.0
2	214	34.9	34.9	-0.9	0.0	-0.9	0	17.8	0.1	17.8	0.0
2	215	34.9	34.9	-0.4	0.0	-0.4	0	17.4	0.1	17.5	0.0
2	217	34.9	34.9	-1.6	0.0	-1.6	0	15.8	0.1	15.9	0.0
2	219	35.0	35.0	7.4	0.0	7.4	0	23.3	0.0	23.3	0.0
3	201	54.9	54.9	0.0	0.0	0.0	9	44.7	0.1	44.8	0.0
3	203	54.9	54.9	-3.7	0.0	-3.7	2	41.0	0.1	41.1	0.0
3	205	54.9	54.9	-8.1	0.0	-8.1	0	32.9	0.1	33.0	0.0
3	207	54.9	54.9	-2.4	0.0	-2.4	0	30.4	0.1	30.5	0.0
3	209	54.9	54.9	-1.8	0.0	-1.8	0	28.7	0.1	28.8	0.0
3	211	54.9	54.9	-1.8	0.0	-1.8	0	26.9	0.1	27.0	0.0
3	214	54.9	54.9	-0.8	0.0	-0.8	0	26.2	0.1	26.2	0.0
3	215	54.9	54.9	-0.4	0.0	-0.5	0	25.7	0.1	25.8	0.0
3	217	54.9	54.9	-1.8	0.0	-1.8	0	24.0	0.1	24.0	0.0
3	219	54.9	54.9	12.1	0.0	12.1	1	36.0	0.1	36.1	0.0
4	201	45.0	45.0	0.0	0.0	0.0	14	48.0	0.0	48.0	0.0
4	203	44.9	45.0	-5.2	0.0	-5.2	2	42.9	0.0	42.9	0.0
4	205	44.9	44.9	-7.9	0.0	-7.9	0	34.9	0.1	35.0	0.0
4	207	44.9	44.9	-2.1	0.0	-2.1	0	32.7	0.1	32.8	0.0
4	209	44.9	44.9	-3.2	0.0	-3.2	0	29.5	0.1	29.6	0.0
4	211	44.9	44.9	-2.3	0.0	-2.3	0	27.2	0.1	27.3	0.0
4	214	44.9	44.9	-3.0	0.0	-3.0	0	24.2	0.1	24.3	0.0
4	215	44.9	44.9	-0.8	0.0	-0.8	0	23.4	0.1	23.5	0.0
4	217	44.9	44.9	-1.4	0.0	-1.4	0	22.0	0.1	22.1	0.0

4	219	44.9	44.9	9.9	0.0	10.0	0	31.9	0.1	32.0	0.0
5	201	45.0	45.0	0.0	0.0	0.0	12	39.1	0.0	39.1	0.0
5	203	44.9	45.0	-4.7	0.0	-4.7	2	34.5	0.0	34.5	0.0
5	205	44.9	44.9	-8.7	0.0	-8.7	0	25.7	0.1	25.8	0.0
5	207	44.9	44.9	-2.7	0.0	-2.7	0	23.0	0.1	23.1	0.0
5	209	44.9	44.9	-3.2	0.0	-3.3	0	19.8	0.1	19.9	0.0
5	211	44.9	44.9	-1.5	0.0	-1.5	0	18.3	0.1	18.3	0.0
5	214	44.9	44.9	-0.4	0.0	-0.4	0	17.8	0.1	17.9	0.0
5	215	44.9	44.9	-0.6	0.0	-0.6	0	17.3	0.1	17.4	0.0
5	217	44.9	44.9	-0.3	0.0	-0.3	0	17.0	0.1	17.1	0.0
5	219	44.9	44.9	15.7	0.0	15.7	0	32.6	0.1	32.7	0.0