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DOCUMENTATION OF A GROUND HYDROLOGY PARAMETERIZATION FOR USE IN THE GISS ATMOSPHERIC GENERAL CIRCULATION MODEL

by

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PREFACE

This documentation is prepared for the Goddard Modeling and Simulation Program (and others with some familiarity with general circulation modeling) to provide a detailed description of a ground hydrology parameterization that can be used in the Atmospheric General Circulation Model (GCM). The preparation of this documentation is part of an ongoing program involving hydrologists with atmospheric modelers to develop realistic interaction between the ground hydrology and the atmospheric components in the GCM. In 1973 the GISS-GCM was documented by Tsang and Karn (TK). In this version the ground wetness is kept constant according to the particular monthly climatic surface relative humidity values for the globe. The ground wetness parameterizations were subsequently revised by GISS modelers to account for the effects of a variable ground wetness on the atmosphere. However, we have found a serious lack of information about how the parameterizations were developed. Our documentation is based primarily on the ground wetness and related sections of the computer coding (Subroutine COMP35).

This documentation is not intended to be self-contained. The reader should refer to TK for further details.

We have developed an off-line testing program for diagnostic and sensitivity studies of the ground wetness and ground temperature parameterization. As a result, some revisions and refinements of the Ground Hydrology Model (GHM) were incorporated in an off-line version, labeled as UCNI.

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PART I

MODEL DESCRIPTION

I. Introduction

The ground hydrology portion of the Goddard GCM models the moisture transport processes related to the earth's surface that were considered to be important to the GCM. The evaporative, sensible and ground heat fluxes that are calculated in the ground hydrology are the principal terrestrial output parameters for the GCM. The principal input parameters to the GHM from the GCM are precipitation, either in the form of rain or snow, and net solar radiation. In the hydrologic cycle the net change in ground cell moisture levels and surface water storage are generally small for long-term averages; then precipitation, evaporation and runoff are the major components of the moisture balance in the GHM.

The present GHM parameterizations are conveniently divided into the following parts:

a) ground wetness and soil parameters,
b) precipitation,
c) evapotranspiration,
d) surface storage of snow and ice, and
e) runout (moisture which is unavailable for evaporation and for cell moisture changes).

In this documentation all of the above moisture transfer processes are considered. In addition, the effects of ground wetness on the ground temperature, the surface specific humidity and the surface temperature will be treated separately. The discussion focuses on understanding the computational aspects of the GHM and how they affect the flux estimates. This documentation does not attempt to develop an extensive derivation or statement of assumptions for the parameterizations at this time. Although an attempt has been made to fully understand the current GHM parameterizations we must point out that the presently available supporting documentation for this report was not completely adequate; therefore we made inferences from the GHM computer code.

Contrary to the traditional hydrology model which is based on the approach of drainage basin system, the development of the GHM parameterizations are designed to capture, in a gross manner, the vertical fluxes for a terrestrial cell 4 degrees latitude by 5 degrees longitude. This type of approach or modeling for hydrologic processes like evapotranspiration, runoff, infiltration, etc. is difficult because of the large size of the cell (which requires arbitrary lumping of hydrologic parameters) and the arbitrary divisions of the latitude and longitude slices that generally cut through drainage basins. The fundamental moisture coupling concept is based on the storage capacity of the soil moisture near the surface to satisfy and therefore regulate the actual evaporative demand. The actual evapotranspiration depends on the characteristics of the ground surface, soil moisture level and the potential atmospheric evaporative demand.

The computer programs and the flow chart for the GHM are described in Sec. III. An off-line ground hydrology model (OLM), devised for diagnostic and sensitivity studies, is discussed in Sec. IV. Some results from numerical experiments are also presented in Sec. IV. The computer program description and flow chart for the OLM can be found in Sec. V. Listings of both programs for the GHM and OLM are in Appendix B with symbols and notations described in Appendix A.

II. Formulation

2.1 Ground Hydrology

The present ground hydrology parameterizations are developed for a ground layer of uniform thickness throughout the globe for each cell following essentially the approach outlined in Arakawa (1972). The fundamental ground moisture concept is based on the availability of moisture in soil to satisfy the evaporative demand of the atmosphere either from bare soil surface or from vegetation canopies. The equation of moisture conservation is given by

$$\rho_w S\, h \frac{\partial w'}{\partial t} = P - E_s - R_o - \rho_w \frac{\partial S_{si}}{\partial t} \qquad (2\text{-}1\text{-}1a)$$

where w' is the ground wetness in [fraction of saturation],

ρ_w is the density of water in [g cm^{-3}],

S is the porosity of soil,

h is the depth of the ground layer in [cm],

P is precipitation in [g cm^{-2} s^{-1}],

E_s is evapotranspiration from the ground surface in [g cm^{-2} s^{-1}],

R_o is "runout" of water from the cell in [g cm^{-2} s^{-1}],

(This is not the conventional hydrologic definition of runoff (Sec 2.1) Runout))

and S_{si} is the surface storage of snow or ice in [cm].

There are two additional conditions governing the ground wetness:

(i) $0 \leq w' \leq 1$ (2-1-1b)

(ii) $w' = 1$, $S_{si} > 0$ (2-1-1c)

Certain critical remarks concerning the fundamental concept of the parameterization are necessary at this point. The present formulation of the GHM incorporates the following basic hydrologic assumptions:

1. surface water storage other than snow and ice is negligible;
2. the presence or absence of a ground water table is ambiguous;
3. ground water storage or storage in the aerated zone below the bulk layer is neglected;
4. horizontal moisture fluxes between adjacent ground cells - surface runoff, flow in the unsaturated zone, groundwater flow, deep vertical percolation, etc. - can be either lumped or calculated by a term R_o in (2-1-1a), and
5. the hydrology of individual ground cells are independent of each other, i.e. mass continuity of the horizontal moisture fluxes is not preserved between adjacent cells.

Another major concern of the parameterizations for the GCM is how the actual evapotranspiration, E_s, in (2-1-1a) can be estimated, because E_s also affects the ground temperature and the sensible heat flux (see Sec. 2.2 and 2.3) in addition to the moisture flux balance.

Ground Wetness and Soil Parameters

The ground wetness in the present parameterization is not clearly defined, causing a certain amount of confusion. Inferences had to be made from the specific values assigned to the soil parameters. The depth of the ground layer is not explicitly specified; instead, a maximum amount of water, w_m or WGM, available for actual evapotranspiration is prescribed for two types of soil layer: WGM = 66.4 g for a "composite soil" and WGM = 4.0 g for a "sandy soil." In addition, an impervious surface is identified by a "ROCK" factor. In reference to UCLA's model [Arakawa, 1972], an amount of 10 g available for actual evapotranspiration was used. Therefore, it appears that WGM in this model is closer to the saturation moisture content than the UCLA's maximum available amount. If we interpret the WGM as the saturation moisture content, then the ground wetness, w' (WET), in this model is defined by volumetric moisture content as a fraction of saturation. We have adopted this definition throughout this documentation. Thus, $w_m = \rho_w Sh$ in (2-1-1a). For the "composite soil," w_m = 66.4 g which is equivalent to specifying S = 0.52 and h = 1.28 m. However, the maximum available moisture of 10 g in UCLA's model has been used as the range over which the actual evapotranspiration is scaled from the potential evaporation by a coefficient β. β is defined as the ratio of actual evapotranspiration to potential evaporation. For the "composite soil," the lower limit of this range is set in the neighborhood of the permanent wilting percentage, PWP (USM) at a ground wetness, w', of 0.1, while the upper limit has a value of 0.25 which is near field capacity, FC. The available amount of moisture for actual evapotranspiration ($0 \leq \beta \leq 1$) is then ASM = 0.15 x 66.4 = 10 g (=FC-PWP) [Salter and Williams, 1965]. The parameterization for evapotranspiration will be discussed later.

For the "sandy soil", ASM = 0.065944 g and USM = 0.024278 g, which are consistent with the field capacity and permanent wilting percentage for a sandy loam [Salter and William, 1965]. The value of w_m = 4.0 g is not consistent with the parameterization outlined in the preceding paragraph. However, if 4.0 g is intended as the maximum available amount of moisture for a desert region, then the layer thickness should be adjusted according to the porosity of the "sandy soil."

Another important aspect of ground wetness in the model concerns the transformation of the initial values of "ground wetness" from the climate data of Schutz and Gates (1972). The ground wetness is first derived from the surface relative humidity data of Schutz and Gates according to

$$GW = \frac{r_s - 15}{85} \ , \ 0 \leq GW \leq 1 \qquad (2\text{-}1\text{-}2)$$

where r_s is the surface relative humidity and GW is the initial "ground wetness" input matrix in the GCM. We cannot find the basis for this transformation. This "ground wetness" is coded as WAT, which is used only for computing the surface relative humidity and the criterion temperature (TK, p. 132). For the ground hydrology, another transformation is carried out according to

$$WET = 0.5*(0.3*GW + 0.4) \qquad (2\text{-}1\text{-}3)$$

which reduces the initial "ground wetness" from the range of (0,1) to (0.2, 0.35). Schutz and Gates' surface relative humidity may be considered as a long-term climatic average value which is proportional to the corresponding quantity near or on the ground surface. It is well known that in moist soil the relative humidity in the soil remains high even if the soil moisture content reaches field capacity [Child, 1969]. This implies that the atmospheric relative humidity near the ground becomes less than unity only when the ground wetness falls below the field capacity. Thus, it is reasonable to scale the range of the surface relative humidity data of Schutz and Gates for the ground wetness between the field capacity and the permanent wilting percentage. Since the ground wetness in this model is considered as depth averaged value, the ground wetness on the ground surface could become less than the permanent wilting percentage during an extended drying cycle. Therefore, the range of the ground wetness scale should be somewhat larger than the interval between the field capacity and the permanent wilting percentage to realistically accomplish the transformation. The upper limit at WET = 0.35 is not unreasonable, but the lower limit at WET = 0.20 should be reduced to a value at or below the permanent wilting percentage.

Precipitation

The precipitation is the primary moisture input in this GHM in the form of rain or snow. The contribution of rain to the ground wetness is by means of the surface infiltration. There is no surface retention of rain water allowed in the model. The surface runoff and seepage are lumped together as the "runout." Snow is first accumulated on the ground surface as a form of surface storage. Whether it will contribute to ground wetness depends on the ground temperature above or below the freezing temperature. Therefore, the melting of snow will affect both the ground wetness and the ground temperature.

Evapotranspiration

The actual evapotranspiration in the GHM is scaled from the potential evaporation by means of a scaling factor, β. The potential evaporation, E_p (PREVAP) in [mm/hr], is given by

$$E_p = \rho_a C_D W_s (q_g^* - q_s) \tag{2-1-4}$$

where ρ_a is the density of air in [gcm^{-3}],

C_D is the drag coefficient,

W_s is the surface wind speed in (ms^{-1}),

q_s is the surface specific humidity at a reference height above the ground surface, and

q^*_g is the ground saturation specific humidity.

The ground saturation specific humidity is a function of the average ground temperature in the diurnal layer. The actual evapotransporation, E_s (AET), is scaled down form (2-1-4) according to

$$E_s = \beta E_p , \qquad 0 < \beta \leq 1 . \tag{2-1-5}$$

For ocean, snow and ice, $\beta = 1$. For land, β is a function of ground wetness, soil characteristics, solar angle and the potential evaporation as the following:

$$\beta = (\beta_{plant} + \beta_{soil})*(1 - ROCK) \tag{2-1-6}$$

where $\beta_{plant} = 1. - \exp\{[-0.1*VPM*\exp(16.75*VPM)/PREVAP]*PLANT\}$, (2-1-7)

$$\beta_{soil} = 1. - \exp[-0.01*VSM*\exp(16.75*VSM)/PREVAP] , \tag{2-1-8}$$

$$VSM = 2.*WET*(ASM + USM) \tag{2-1-9}$$

and

$$VPM = 0.1*VSM/USM + 0.2*\left(\frac{VSM - USM}{ASM}\right) \tag{2-1-10}$$

It has been suggested that the parameterizations of (2-1-7) to (2-1-10) are based on Van Bavel (1966) field study. However we are not able to pin down these relationships quantitatively. Therefore, a study of the range of variation of the above parameters was carried out as follows. The PLANT factor given as a function of solar angle, Z,

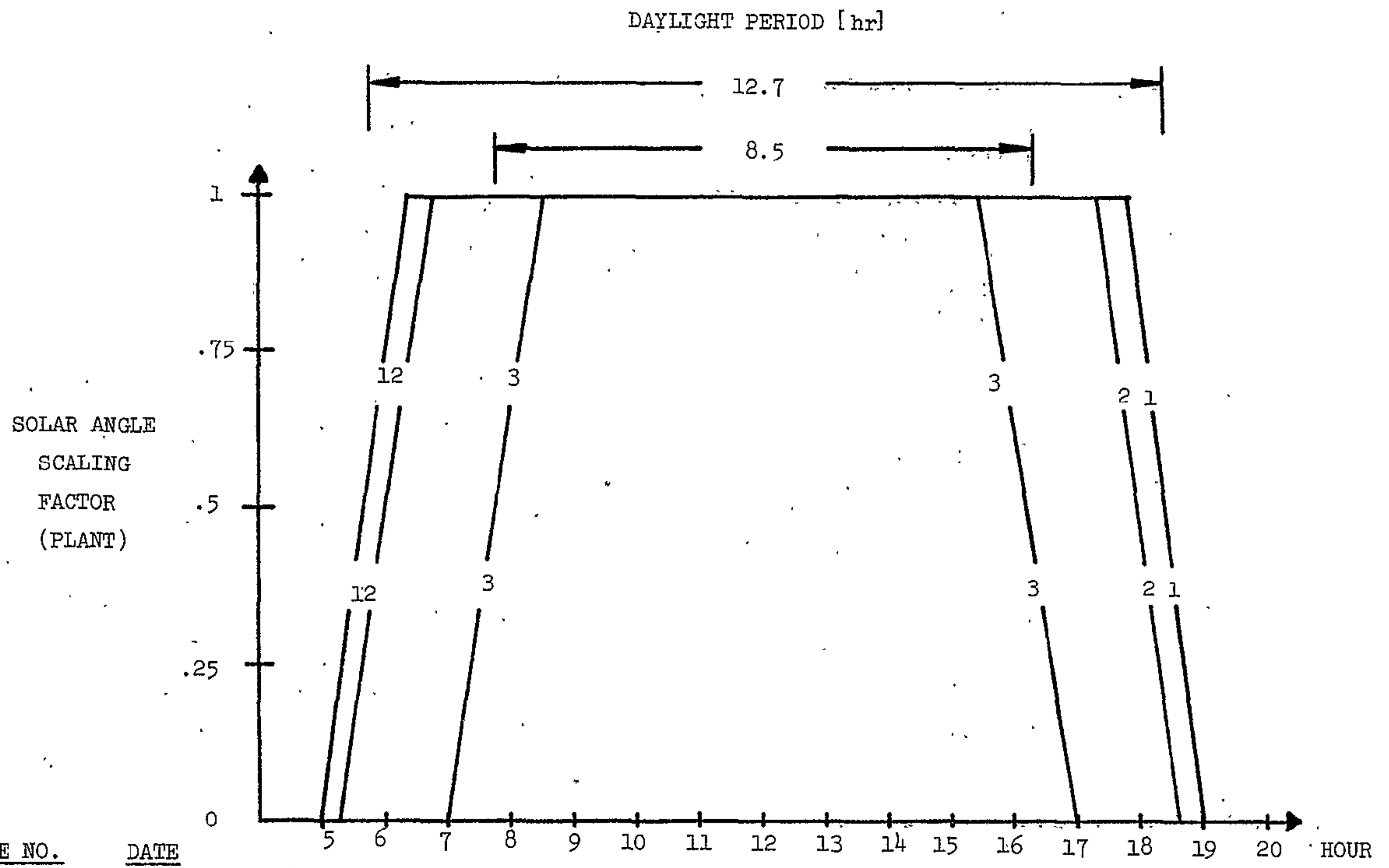
$$PLANT = \min\left(1.0, \frac{\cos(Z)}{0.2588}\right) \tag{2-1-11}$$

is shown in Figure 1. It is interesting to note that for the 32° N Latitude, the ratio of daily maximum solar radiation at the ground between Dec. 21 and June 21 is 0.4 [Koberg, 1962] while the ratio of average PLANT factor derived from Figure 1 is 0.67. Similarly, the ratios for April 21 and August 21 were found to be 0.85 and 0.95, respectively. The comparison indicates that the PLANT factor based on the solar angle is overestimated based on Koberg. For specified values of E_p and PLANT, the scaling factor β given in (2-1-6) is plotted in Figures 2(a) and (b) for the composite and sandy soil. These figures indicate that β_{plant} dominates the actual evapotranspiration scaling factor. The intent of the specified values of field capacity and permanent wilting percentage in relation to β is not evident from the coded parameterizations. In an attempt to understand the effect of field capacity and permanent wilting percentage values we compared β with the parameterization of agricultural crops and a soil [Monteith, 1975]. This is presented in Figure 3 which shows that the current parameterizations represent a revision of the UCLA values and do not follow conventional agricultural type variations. For $E_p = 0.1$ mm/hr or approximately 1.2 mm/day if transpiration is shut off during the night, β in the current model comes closest to the linear variation of the UCLA scaling factor between FC and PWP explained in Arakawa [1972].

In summary we see that the scaling factor for the calculation of actual evapotranspiration is a function of solar angle, E_p, soil type and moisture content and that in a gross sense the family of curves presented in the examples of Figure 3 is consistent with the previous UCLA formulation. However, there exists an inconsistency for the scaling factor in relation to the field capacity and permanent wilting percentage. If a parameterization embodies pertinent soil characteristics such as field capacity and permanent wilting percentage, the scaling factor should approximate the simple rule: a) once ground wetness has exceeded field capacity the actual evapotranspiration rate should approach the potential rate and b) at or below field capacity the scaling factor, β, should fall below 1 and approach zero as the permanent wilting percentage is reached. The parameterization in this model does not follow this rule, tending to scale down the potential rate excessively. If realistic evaporation fluxes from the model are to be expected the potential rate would have to be significantly higher to compensate for the lower values of the scaling factor β. On the other hand, the value of β is limited by this potential rate in the exponent of (2-1-7) and (2-1-8). Therefore, it appears that the actual evaporation rate is in general underestimated in this model. This may significantly affect the calculation of moisture fluxes as an input to the GCM. See Section IV for further details.

Surface Storage of Snow and Ice

The surface storage in the GHM is in the form of snow, ice or mixed ice and water. There is no surface storage of rain water on the ground surface during or after a rainfall. Thus the absence of surface storage inherently affects the computed values of ground wetness. The storage affects not only the ground wetness but also the ground temperature through transfer of latent heat. The thickness of snow and ice and the fraction of ice in mixed ice and water are updated every time step. The surface storage in the ground wetness equation (2-1-1) and the latent heat transfer term in the ground temperature equation (see Sec. 2.2) are adjusted simultaneously. Again the "ROCK" factor characterizing the impervious surface is appropriately incorporated in the adjustment of the transfer processes.



LINE NO.	DATE	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1	JUNE 21	90	79	66	53	41	28	16	9	16	28	41	53	66	79	90	ZENITH
2	APRIL 21 & AUG 21	90	83	71	59	46	35	25	20	25	35	46	59	71	83	90	ANGLE
3	DEC 21	90	90	90	80	70	62	58	55	58	62	70	80	90	90	90	[°]

FIGURE 1. SOLAR ANGLE SCALING FACTOR, PLANT, AS A FUNCTION OF SOLAR ZENITH ANGLE AT 32°N

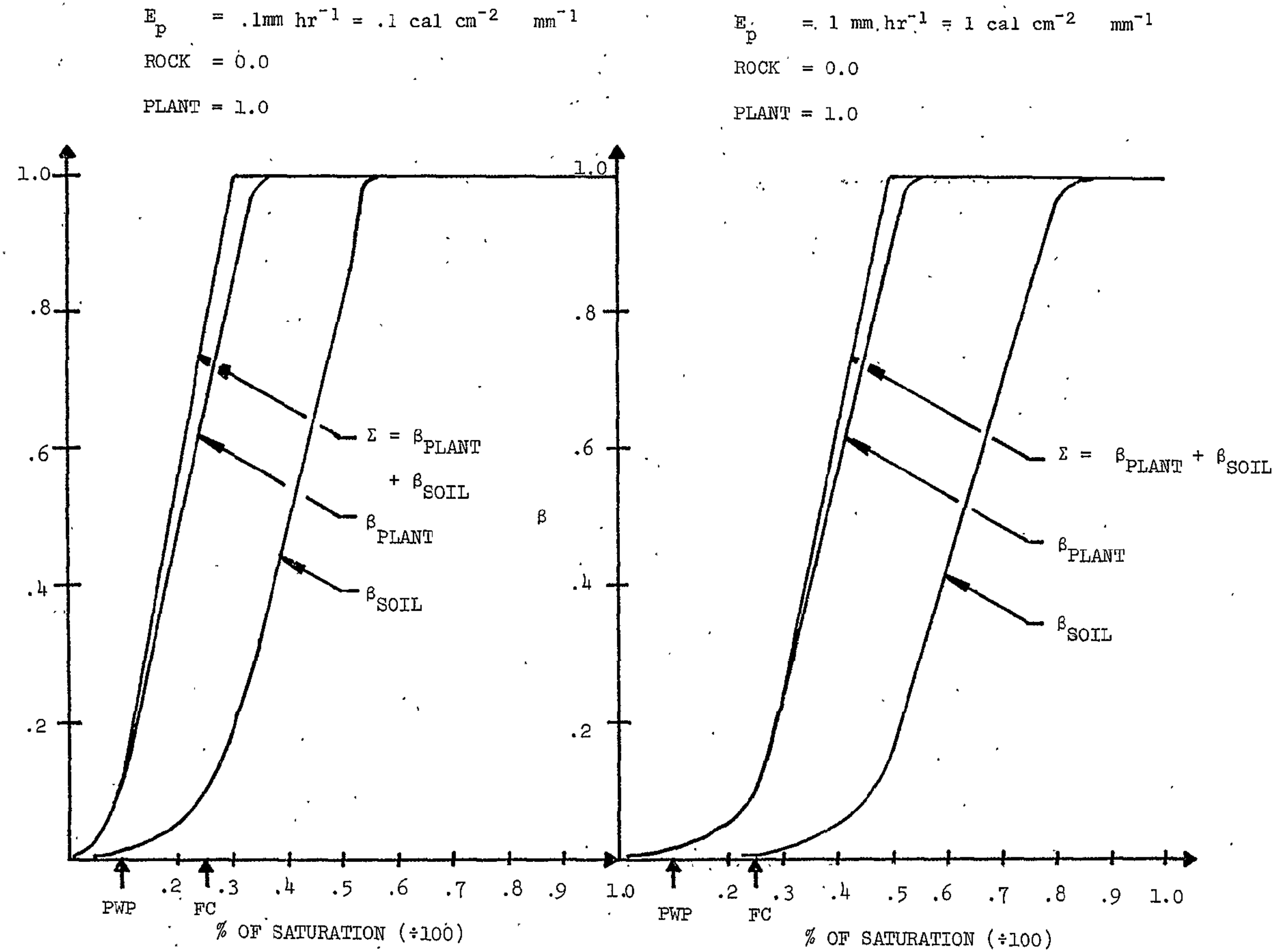


FIGURE 2A. β, EVAPORATION SCALING FACTOR FOR COMPOSITE SOIL

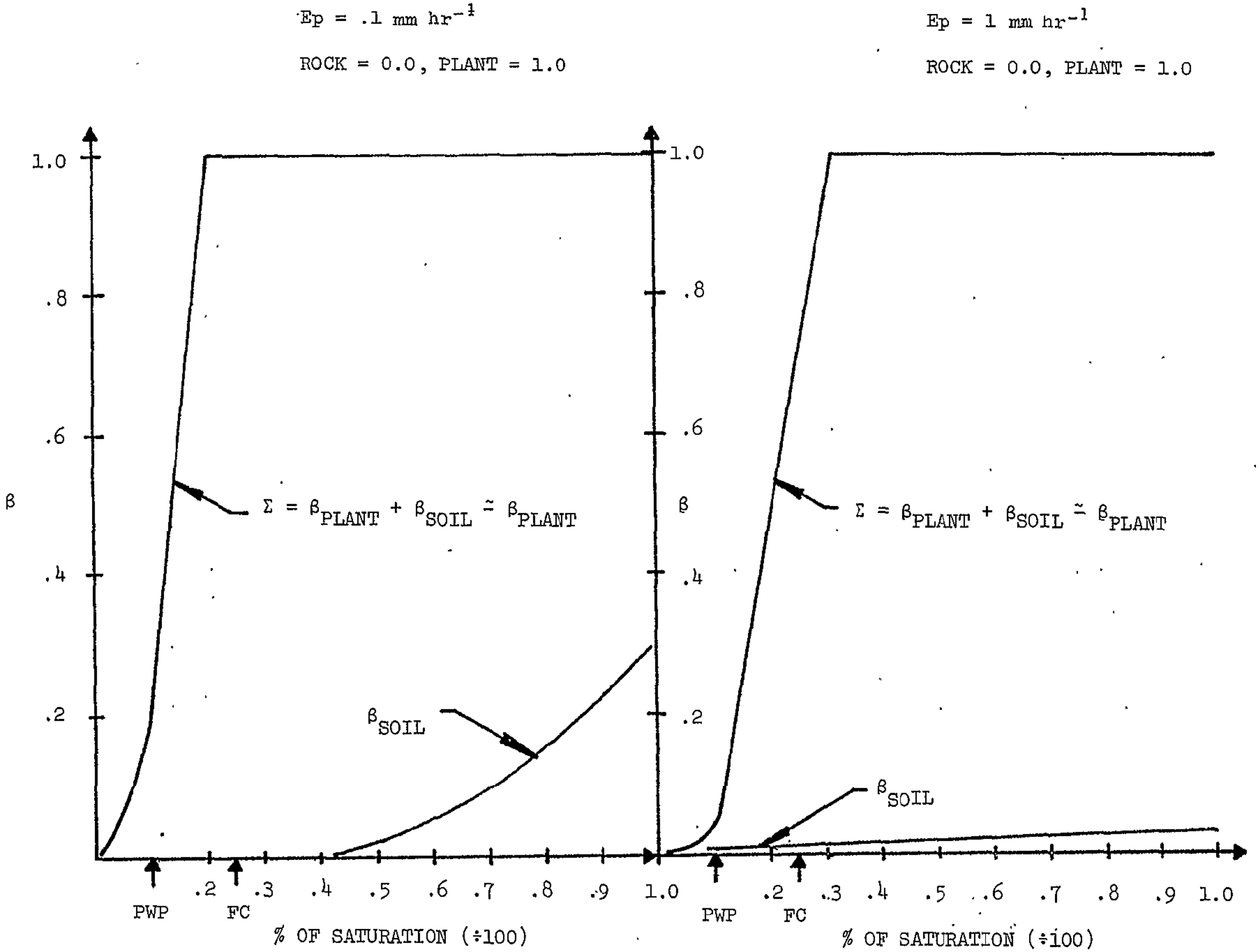


FIGURE 2B. β, EVAPORATION SCALING FACTOR FOR DESERT SOIL

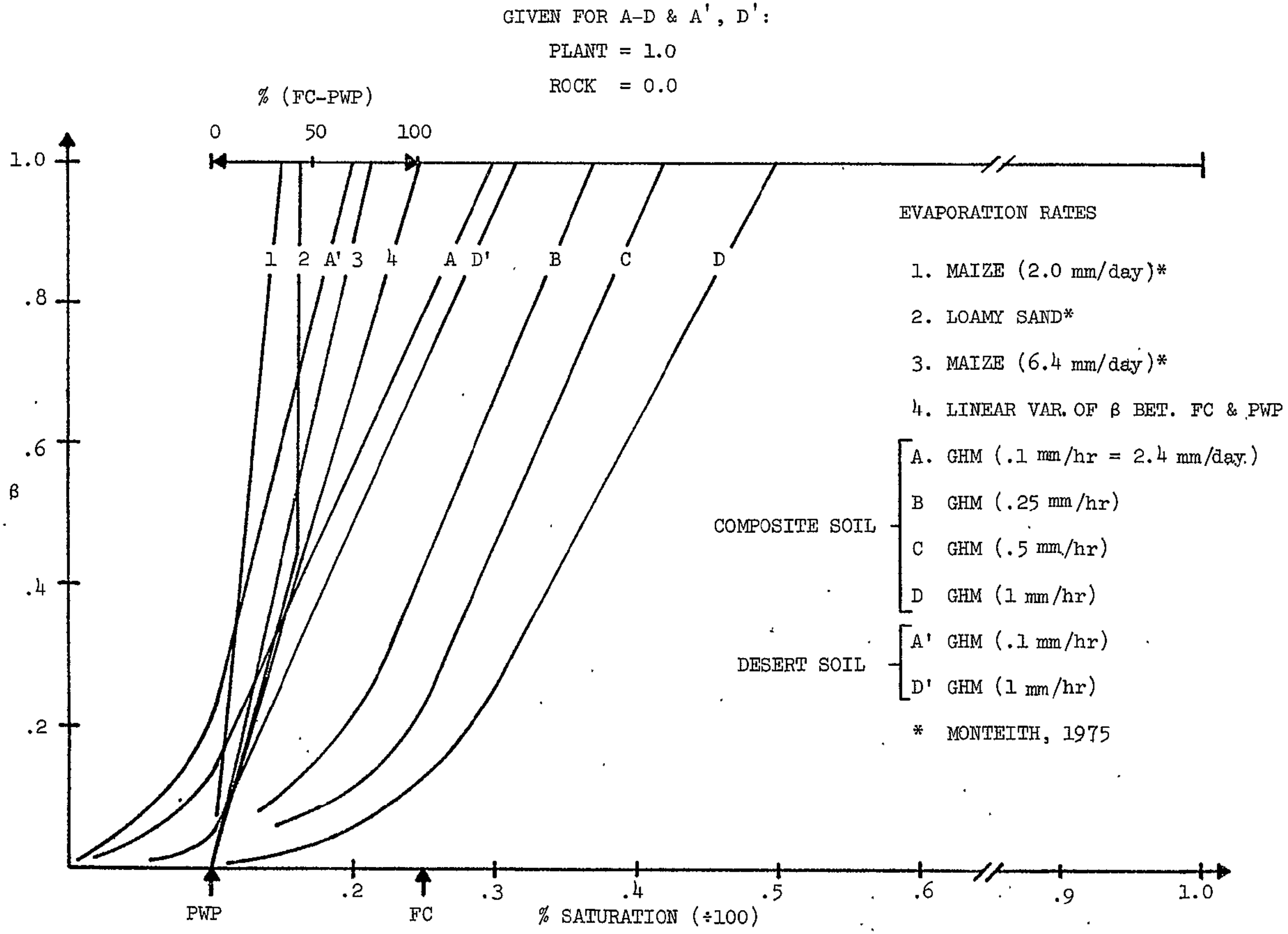


FIGURE 3. EVAPORATION SCALING FACTOR, β, COMPARISONS

Runout

The term, "runout," in the present GHM has a special meaning which is different from the "runoff" conventionally used in hydrology. Runoff is generally considered to be the continuous gravity movement of water on the ground surface and in channels with a characteristic magnitude which should be consistent with the intensity of precipitation, infiltration and topography of the ground surface [Ward, 1975] The runout in this model is divided into two regimes, depending on the relative magnitude of the rainfall rate and the maximum surface infiltration rate. Runout is defined as, in a gross sense, the sum of all outgoing moisture fluxes other than evapotranspiration from a ground cell. In view of the assumption of hydrologically isolated ground cells, the runout moisture neither enters the surrounding cells nor is being stored in a lower ground layer. Therefore, the amount of runout estimated in the model represents the portion of rain or melting snow which cannot contribute to the ground wetness and evapotranspiration. Runout consists of (a) surface runoff, (b) percolation and (c) any excess of moisture above the capacity of the soil layer ($w' > 1$).

Before calculating the runout, an infiltration rate is first calculated as one half of

$$\mathrm{BBFACT} = 2.*\mathrm{FILTF}*\mathrm{EXP}(-1.75*(\mathrm{ADINF}-0.5)) \quad \text{in [cm/hh]} \qquad (2\text{-}1\text{-}12)$$

where

$$\mathrm{FILTF} = [1.77.*\mathrm{EXP}\{-0.036*(\mathrm{TG}-\mathrm{TICE})\} + 0.44562]^{-1} \qquad (2\text{-}1\text{-}13)$$

and

$$\mathrm{ADINF} = 1.25*(2.*\mathrm{WET}-0.2)-0.5 \qquad (2\text{-}1\text{-}14)$$

where TG and TICE are the ground and freezing temperature. FILTF is a temperature dependent parameter as shown in Figure 4 and ADINF is a function of ground wetness. Both ADINF and BBFACT as a function of ground wetness are shown in Figure 5. However, the physical implications of ADINF and FILTF are not known at this time. When the rainfall rate exceeds twice the maximum surface infiltration rate (MSIR), the excess contributes to the runout, or

$$\text{RUNOFF} = \text{RAIN} - .5*\text{BBFACT} \text{ in } [\text{cm/hh}] \qquad (2\text{-}1\text{-}15)$$

When the rainfall rate is less than twice the BBFACT, the runout is calculated by

$$\text{RUNOFF} = .5*(\text{RAIN})^2/\text{BBFACT} \text{ in } [\text{cm/hh}] \qquad (2\text{-}1\text{-}16)$$

These formulas are shown graphically in Figures 6 and 7. Again, the hydrologic basis for (2-1-15) and (2-1-16) is not known to us.

Given the ground temperature and soil moisture values one can first estimate the BBFACT from Figure 5. Then, for a given rain input one can obtain the runout by using Figure 6. Soil characteristics or vegetal cover effects are not considered in obtaining runout values. What are the characteristics values of runout? The following numerical example will help answer this question. Since typical global soil moisture contents are generally less than field capacity, WET = .25 should be a reasonable value for a field capacity or the upper limit of mean soil moisture values. Taking a typical ground temperature, say 20°C, one finds, from Figure 5 a value for the BBFACT of 4.75. In Figure 6 we see the following for BBFACT = 4.75:

RAIN [cm/hh]	RUNOFF [cm/hh]
1.0	.1
2.0	.4
3 0	.8
4.0	1.5

A review of the computer output from the GCM indicates that the rainfall rates rarely exceed 1 [cm/hh]. The above table implies that runout is generally a small part of rain or that the major portion of rain contributes to cell moisture changes. However, a recent study indicates that, on a global scale, the ratio of runoff (which is a part of runout in GHM) to rainfall over the continent is 0.36 [Baumgartner, 1975]. Finally, runout versus soil moisture for a given temperature is plotted for various rain values in Figure 7. In the model, the runout is adjusted for the percentage of ROCK on the surface. The effect of a nonzero value of ROCK is to increase runout which reduces the surface infiltration rate.

In order to balance (2-1-1a) the runout is computed according to (2-1-12) through (2-1-16). Two corrections of runout from the cell are made by (1) limiting the ground wetness to be less than unity as (2-1-1b) and (2) percolation by reducing the ground wetness in an amount of 5% if the ground wetness exceeds half of its maximum value.

In summary, the runout parameterizations are a function of rain, cell moisture content and temperature. This represents a change over the previous UCLA model which used a linear scaling factor of the cell moisture to obtain a value of runoff. From the numerical example presented above it has been shown that runout is a small part of rainfall rate and hence plays a minor role in the calculation of cell moisture changes in this model. However,

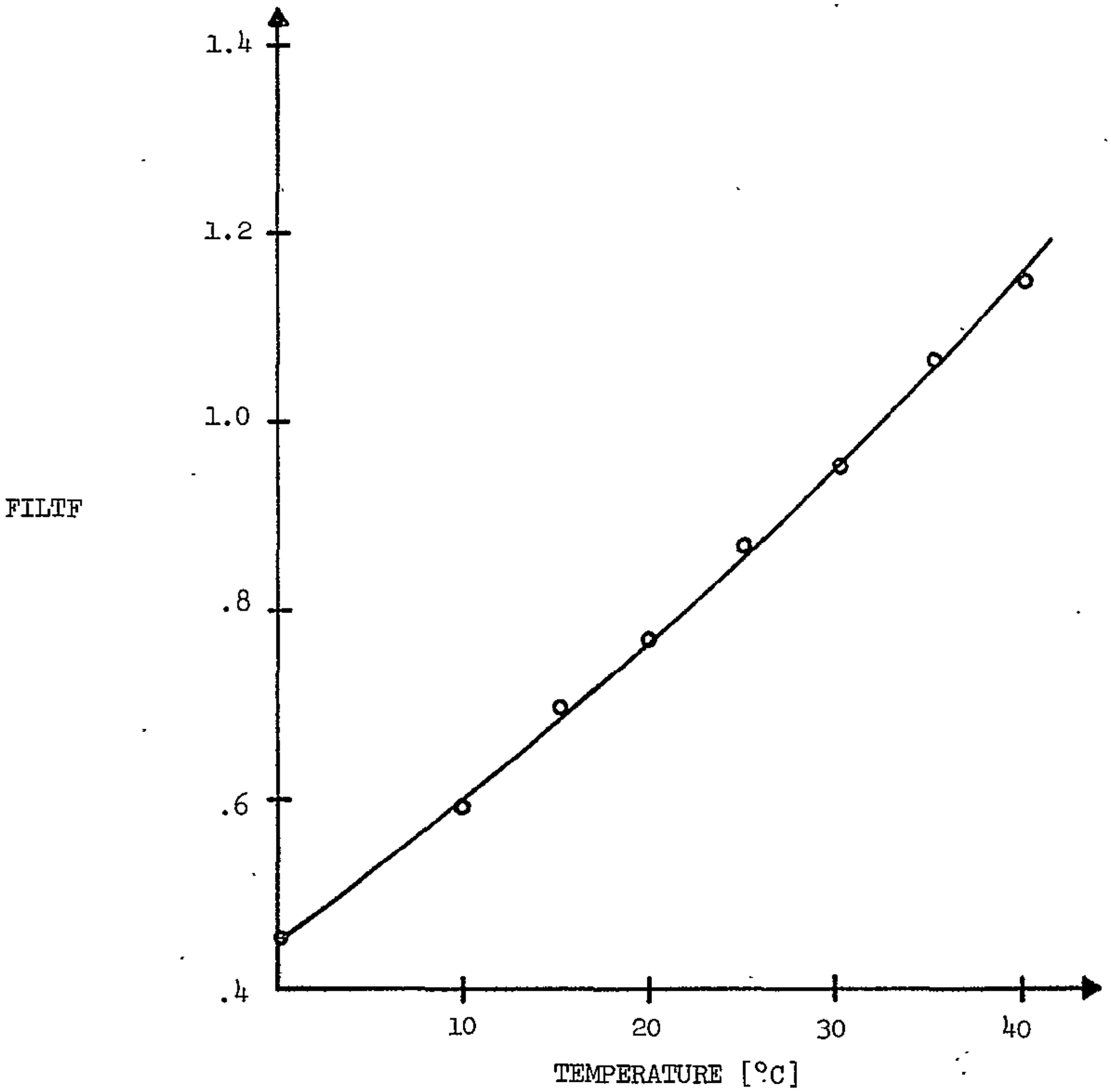


FIGURE 4. FILTF VERSUS TEMPERATURE

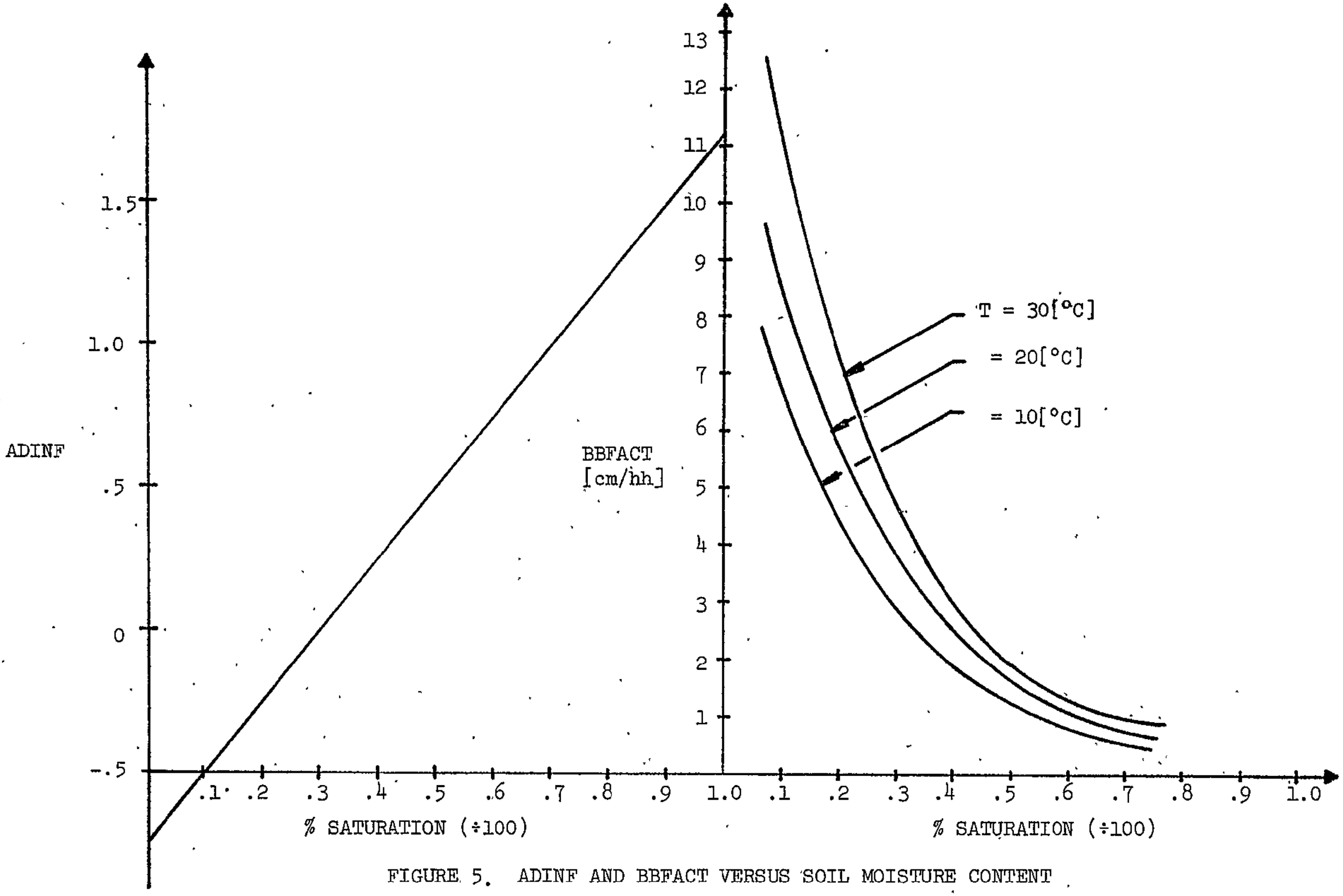


FIGURE 5. ADINF AND BBFACT VERSUS SOIL MOISTURE CONTENT

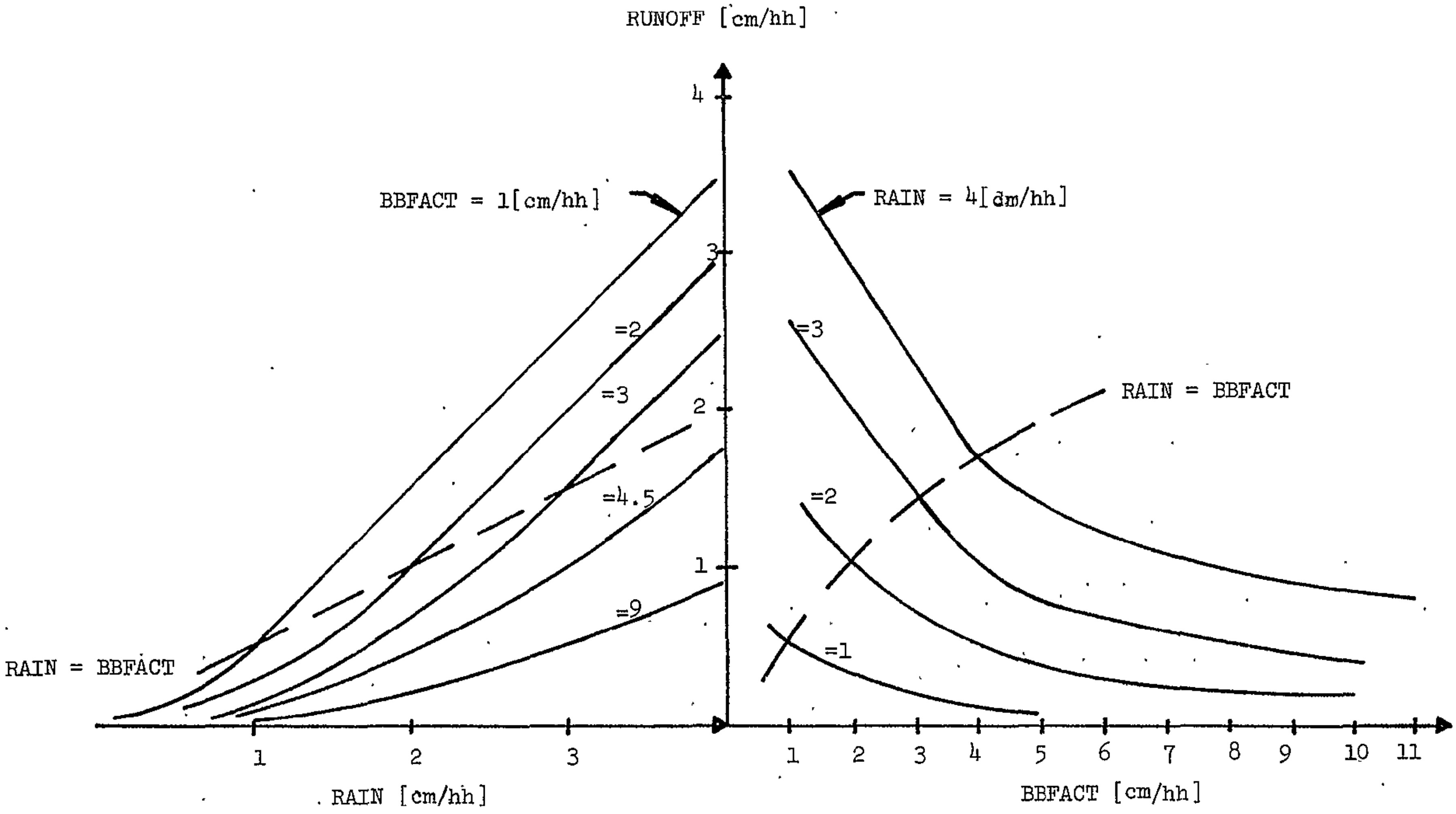


FIGURE 6. RUNOFF VERSUS RAIN FOR VARIOUS VALUES OF BBFACT AND RUNOFF VERSUS BBFACT FOR VARIOUS VALUES OF RAIN

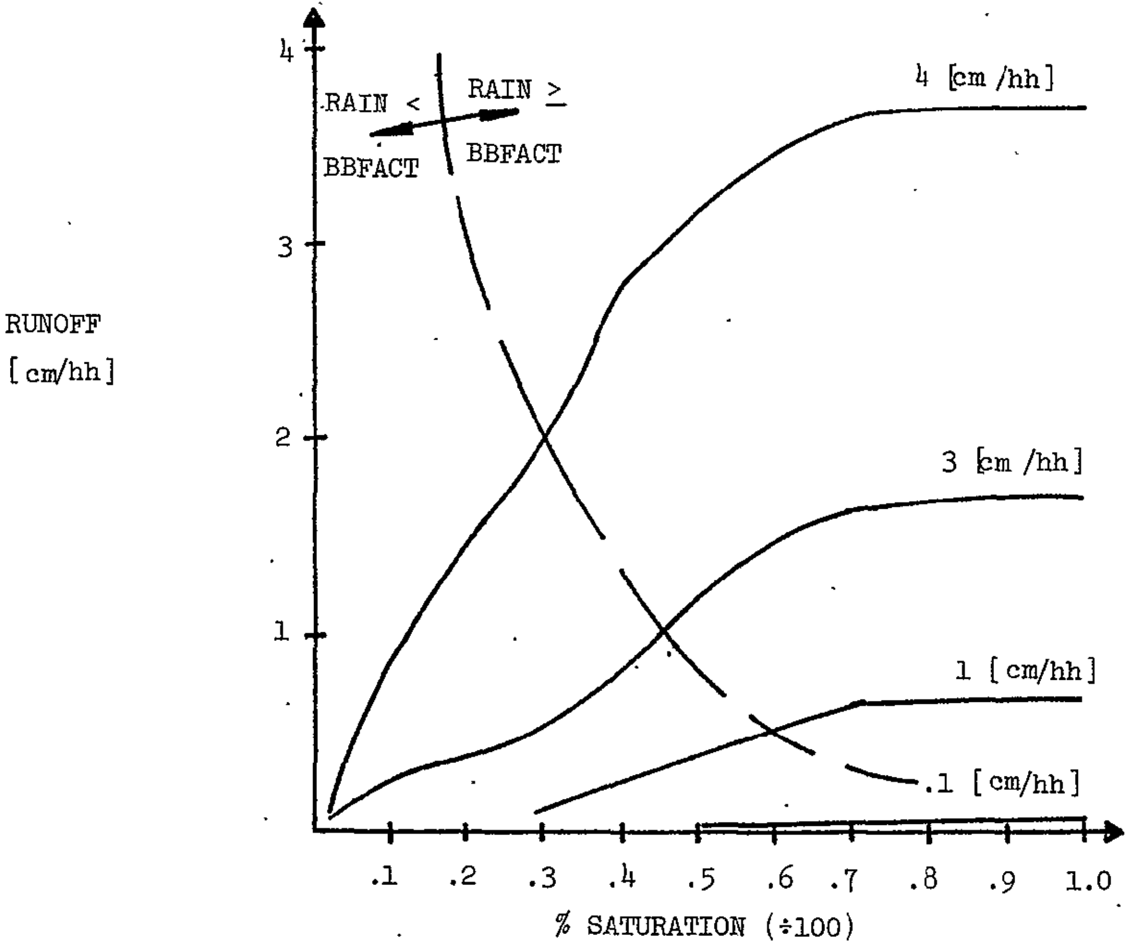


FIGURE 7. RUNOFF VERSUS SOIL MOISTURE FOR VARIOUS VALUES OF RAIN

Baumgartner has shown that runoff, which is less than runout, is not negligible; hence the GCM calculations of cell moisture are questionable.

2.2 Ground Temperature

The ground temperature in the GCM has been documented in TK. As the ground temperature is intrinsically coupled with the ground wetness, we intend to discuss only the terms in the ground temperature equation involving the ground wetness. The ground temperature is given by

$$C \frac{\partial T_g}{\partial t} = R_N - F_s - LE_s + Q_m + S_i \qquad (2\text{-}2\text{-}1)$$

where T_g is the ground temperature in the diurnal ground layer [Arakawa and Mintz, 1974] in [°K],

C is the total heat capacity in [cal cm^{-2} deg^{-1}],

R_N is the net radiation flux at the ground surface positive downward in [ly day^{-1}],

F_s is the upward flux of sensible heat in [ly day^{-1}],

LE_s is the upward flux of latent heat in [ly day^{-1}],

Q_m is the heating or cooling due to conduction through sea ice from the ocean below in [ly day^{-1}], and

S_i is the transfer of latent heat due to melting of ice or snow or due to freezing of water in [ly day^{-1}].

The ground temperature equation is discretized with respect to time by an implicit scheme and is updated in the time step before updating the ground wetness. The finite difference equation is given in TK without the term, S_i, as the following:

$$T_g^{\,n+1} = T_g^{\,n} + \frac{\eta_3 \Delta t \left[R_N - F_s - LE_s + Q_m + S_i\right]^n}{C + \left[\frac{\partial R_N}{\partial T_g} + \frac{\partial F_s}{\partial T_g} + L\frac{\partial E_s}{\partial T_g} - \frac{\partial Q_m}{\partial T_g}\right]^n} \qquad (2\text{-}2\text{-}2)$$

where the superscripts n+1 and n indicate the time step and $n_3 \Delta t$ is the time interval used in the subroutine.

In Equation (2-2-2), the terms, F_s, LE_s, $\frac{\partial F_s}{\partial T_g}$, $L \frac{\partial E_s}{\partial T_g}$, S_i and C, involve ground wetness. The latent heat flux, LE_s, or the actual evapotranspiration, E_s, has been discussed in Sec. 2.1. The sensible heat flux, F_s, will be discussed in Sec. 2.3, because both the ground temperature and the surface temperature are affected by ground wetness. The total heat capacity is defined as

$$C = \left(\frac{c\lambda}{\omega}\right)^{1/2} \text{ in } [\text{cal cm}^{-2} \text{ deg}^{-1}] \qquad (2\text{-}2\text{-}3)$$

where c is the specific heat capacity in $[\text{cal cm}^{-3}\text{deg}^{-1}]$,

λ is the termal conductivity in $[\text{cal cm}^{-1} \text{ s}^{-1} \text{ deg}^{-1}]$, and

ω is the diurnal frequency in $[\text{s}^{-1}]$.

The values of C are given as the following:

for ocean $C = \infty$. (2-2-4a)

for snow, $C = 2.3$. (2-2-4b)

for ice, $C = 5.1$. (2-2-4c)

for frost,

$$C = \left[(0.331 + 0.075w')(2. + 2.5w') * 0.001 * \frac{24\text{x}3600}{2\pi}\right]^{1/2} \qquad (2\text{-}2\text{-}4d)$$

for mixed water and ice,

$$C = \left[(0.276 + (0.11 + 0.15w')(w' - 0.5w_i))(1 + w' - 0.25w_i) * .002 * \frac{24*3600}{2\pi}\right]^{1/2} \qquad (2\text{-}2\text{-}4e)$$

where w_i = the portion of ice in w' = (WET).

For soil, the original UCLA formula, (2-2-4e), with $w_i = 0$ is replaced in the present model by

$$C = [(.3 + VSM)*(1+10.*VSM)*0.001 * \frac{24*3600}{2\pi}]^{1/2} \qquad (2\text{-}2\text{-}4f)$$

where VSM = 2.0*WET*(ASM+USM), (2-1-9)

ASM = available soil moisture in [% of saturation ÷ 100], and

USM = unavailable soil moisture in [% of saturation ÷ 100].

The proper use of (2-2-4f) requires an appropriate definition of WET. This has been discussed in Sec. 2.1. Therefore, WET in (2-2-4f) is the ground wetness defined in this model despite the fact that the maximum available amount of moisture used in this model is different from UCLA's value.

The transfer of latent heat, S_i, due to melting of ice or snow or due to freezing of water is updated at each time step according to the ground temperature below or above the freezing temperature.

2.3 Surface Conditions in the Atmosphere

The formulation of the atmosphere-ground hydrology interaction depends on parameterization of both the planetary boundary layer (PBL) and ground hydrology. In TK, the boundary layer is taken to be the bottom half of the ninth layer in the GCM and the location of the "surface," the bottom of the ninth layer, with respect to the ground surface is not specified. We shall follow the same approach in this documentation. The atmospheric conditions that are coupled with the ground hydrology are related to the source terms in the governing equations of the GCM (see TK, pp. 7-13); namely,

(1) the surface wind and stability conditions

(2) the heat flux

(3) the moisture flux, and

(4) the solar radiation.

Most of the discussions in the following paragraphs can be referred to TK (Chapter XI, pp. 109-191).

Surface Wind and Stability Conditions

Since the lower surface of the GCM or PBL is not explicitly specified, we assume that the "surface" is located at the level of anemometer height, say, 8 m from the ground surface. The surface wind components are extrapolated from the values at the n-th and n-1 th layers with respect to their σ coordinates by

$$\frac{u_n - u_{n-1}}{\sigma_n - \sigma_{n-1}} = \frac{u_s - u_n}{\sigma_s - \sigma_n} \qquad (2\text{-}3\text{-}1)$$

where the subscripts n and s refer the quantities to the center of the n^{th} layer and to the "surface" and u is the x-component of wind velocity. The y-component of velocity, v_s, is computed in a similar manner. The magnitude of the surface wind velocity is then

$$W_s = (u_s{}^2 + v_s{}^2)^{1/2} \text{ in } [\mathrm{m\ s^{-1}}] \qquad (2\text{-}3\text{-}2)$$

Special provisions are made for computing wind speeds at the north and south poles. The surface wind affects not only the surface skin friction but also the moisture and heat fluxes on the ground surface. These fluxes depend also on the drag coefficient, C_D. For a neutrally stable atmosphere when the surface temperature, T_s, and ground temperature, T_g, are equal,

$$C_D \equiv C_{D_o} = \min[(1.0 + 0.07\, W_s{}^2)/1000.,\ 0.0025], \text{ for ocean} \qquad (2\text{-}3\text{-}2a)$$

$$= 0.002 + 0.006(Z_s/5000), \text{ for not ocean} \qquad (2\text{-}3\text{-}2b)$$

where Z_s is the ground surface elevation in [m].

In general,

$$C_D = C_{D_o}/[1-7.0(T_g - T_s)/W_s^2] \ , \ T_g < T_s \qquad (2\text{-}3\text{-}3a)$$

$$= C_{D_o} \cdot [1 + \sqrt{(T_g-T_s)/W_s^2}] \ , \ T_g \geq T_s \ . \qquad (2\text{-}3\text{-}3b)$$

These coefficients will be used in the moisture and heat flux computations.

Heat Flux and Surface Temperature

The sensible heat flux on the ground surface is computed according to

$$F_s = C_p \rho_a C_D |W_s| (T_g - T_s) \text{ in } [\text{ly day}^{-1}] \qquad (2\text{-}3\text{-}4)$$

which is coupled to the heat flux in the PBL by the turbulent diffusion equation

$$F_h = -C_p \rho_a K \frac{\partial T}{\partial Z}\bigg|_{PBL} \qquad (2\text{-}3\text{-}5)$$

where ρ_a is the air density in [g cm^{-3}],

C_p is the specific heat at constant temperature in [cal g^{-1} deg^{-1}], and

K is the vertical eddy diffusivity in [m^2 s^{-1}].

The horizontal convergence in the boundary layer and geopotential difference between its top and bottom are neglected, then the surface temperature, T_s, can be computed by equating the above two equations as described in detail in TK. However, we would like to point out one computation directly involving the ground wetness for the temperature gradient, $\frac{\partial T}{\partial z}\Big|_{PBL}$, in (2-3-5). The temperature gradient is given by

$$\frac{\partial T}{\partial z}\bigg|_{PBL} = \frac{(T_{TB} - T_s) - (T_{TB} - T_s)_{crit}}{(\Delta z)_{PBL}} \qquad (2\text{-}3\text{-}6)$$

and $(T_{TB} - T_s)_{crit} \doteq (1 - r_s)(T_{TB} - T_s)_{d.a.} + r_s(T_{TB}-T_s)_{m.a.}$ (2-3-7) where $(\Delta z)_{PBL}$ is the thickness of the PBL and the subscripts, TB, s, (d.a.) and (m.a.) refer to the top of PBL, the "surface" or the bottom of PBL, dry adiabatic and moist adiabatic, respectively. The relative humidity on the "surface", r_s, is derived from

$$r_s = \frac{2w' r_n}{w' + r_n} \quad , \text{ and } w' = \text{WET} \qquad (2\text{-}3\text{-}8)$$

where w' is the ground wetness (see TK, p. 132). It appears that the ground wetness is treated like the relative humidity on the ground surface in (2-3-8). The relation between the ground wetness and the relative humidity in a soil layer has been discussed in Sec. 2.1. In order to use (2-3-8), the following transformations are made:

WAT = 2.*(1.66667*2.*WET - 0.66667) (2-3-9a)

for the "composite soil", and

WAT = 0.2*(2.*WET - 0.26909) . (2-3-9b)

for the "sandy soil." WAT is used as w' in (2-3-8) instead of WET. In a way, it is an inverse transformation of (2-1-3), which changes the ground wetness back to the "initial ground wetness" (Schutz and Gates' surface relative humidity).

On the other hand, the surface specific humidity is computed by another method using (2-3-10) as discussed in the following section.

Moisture Flux

The moisture flux from the ground is equal to the actual evapotranspiration given by (2-1-4) and (2-1-5). In these equations, the surface specific humidity, q_s, is derived by equating the flux in the PBL to the flux from the surface as the following;

$$q_s = \frac{EVACO*q_g + EDV*q_n}{EVACO + EDV} \tag{2-3-10}$$

where q^*_g and q_n are the saturation specific humidity at the ground surface and the specific humidity at the 9th level in the GCM. EVACO = $\beta C_D W_s$, an evapotranspiration coeffient in (2-1-4) and (2-1-5). EDV = $K/(\Delta z)_{PBL}$, a surface layer eddy coefficient. Physically, (2-3-10) implies a constant moisture flux through the PBL similar to the assumption used in deriving the surface temperature. However, in case of supersaturation, the surface temperature and specific humidity are adjusted to account for the heating effect of condensation and the releasing of moisture (see TK, pp. 135-136).

Solar Radiation

The radiation model in the GCM has not been documented at this time; therefore, it must be referred to the forthcoming documentation. In running the GHM on-line with the GCM or off-line alone, the radiation terms in the ground temperature equation (2-2-1) are treated either as the version given in TK or as input quantities from the GCM output.

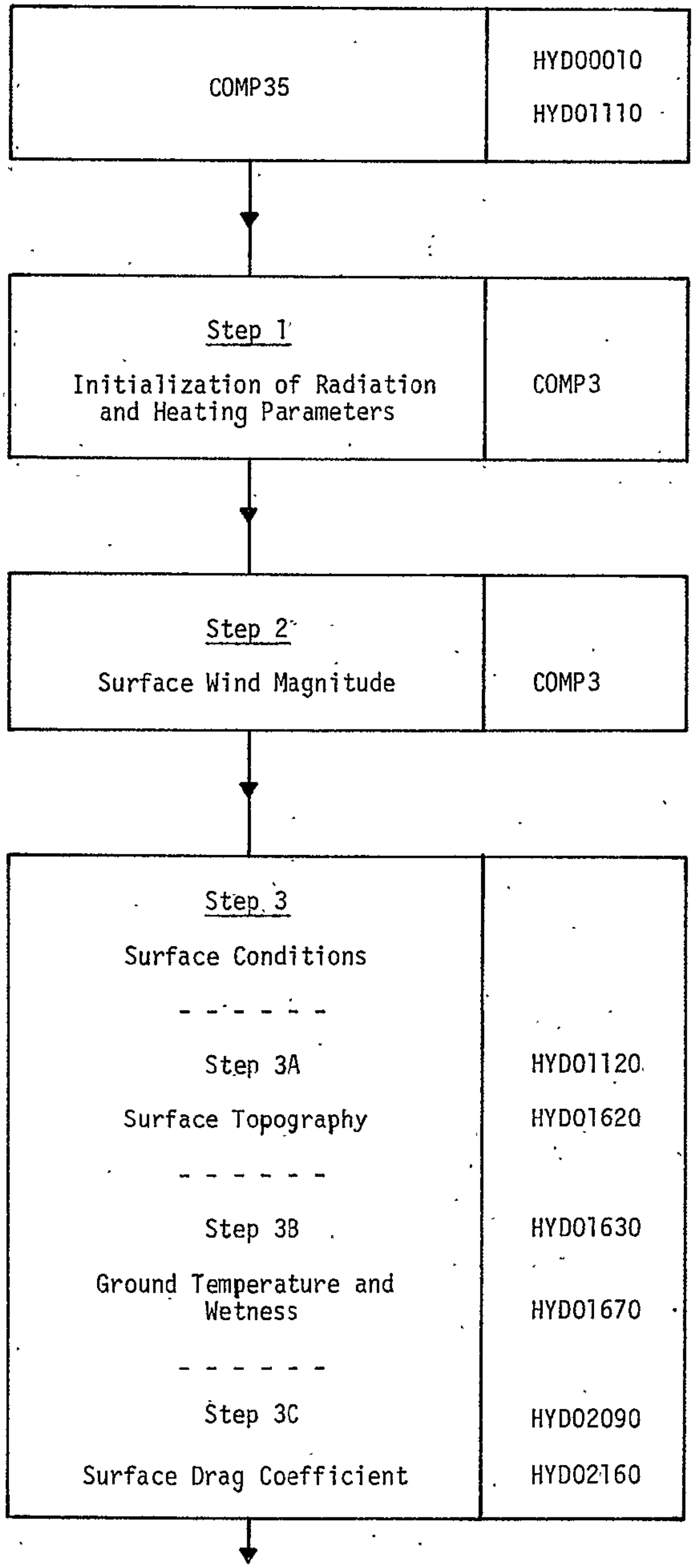
III. Description of the Computer Program for the GHM

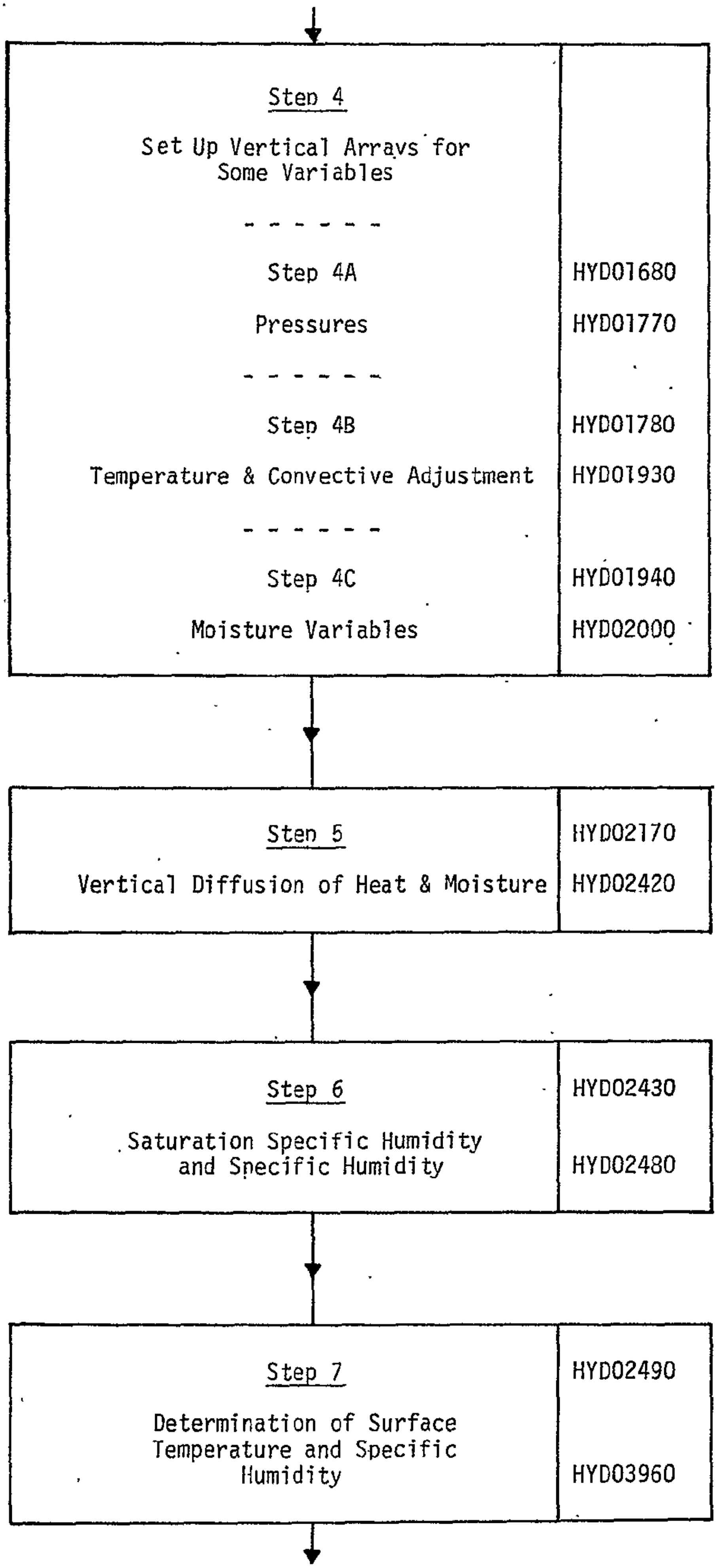
Subroutine COMP35

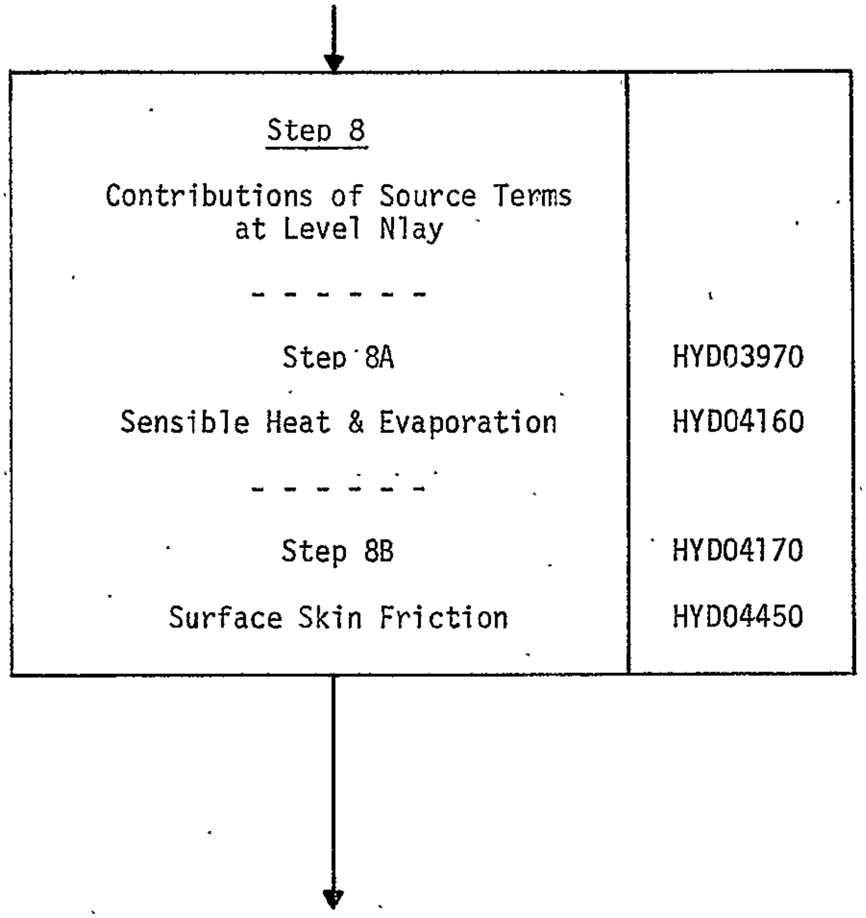
The ground hydrology model resides in subroutine COMP35 in the GCM computer program. The function of COMP35 is to evaluate the hydrology related source terms in the governing equations and their effects on the atmospheric motion. It should be noted that COMP35 is different from COMP3 in TK in that the ground hydrology parameterizations were later added. There are 16 steps in COMP35 as in COMP3 as illustrated in the flow chart. Steps 1, 2, 3, 6 and 12 interact directly with the GHM. The major ground hydrology parameterizations are incorporated in Steps 7 and 14. Step 7 deals with the coupled effects of the ground hydrology and the atmosphere on the "surface" temperature and humidity as discussed in Sec. 2.3 and the parameterizations of evapotranspiration for the latent heat flux. In Step 14, the ground temperature is first updated according to the scheme outlined in Sec. 2.2 and then ground wetness change is calculated on the basis of (2-1-1).

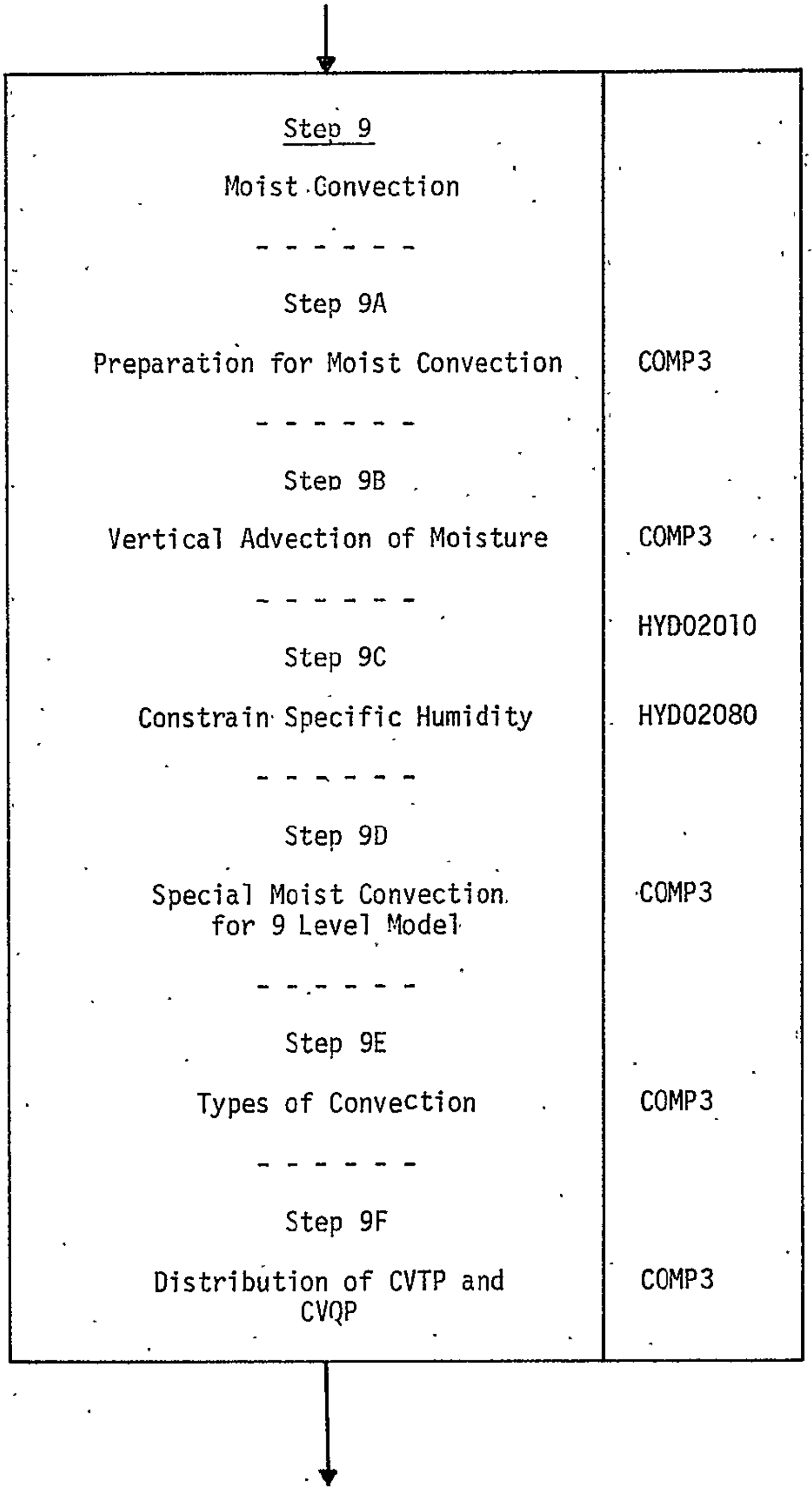
FLOW CHARTS

COMP35:

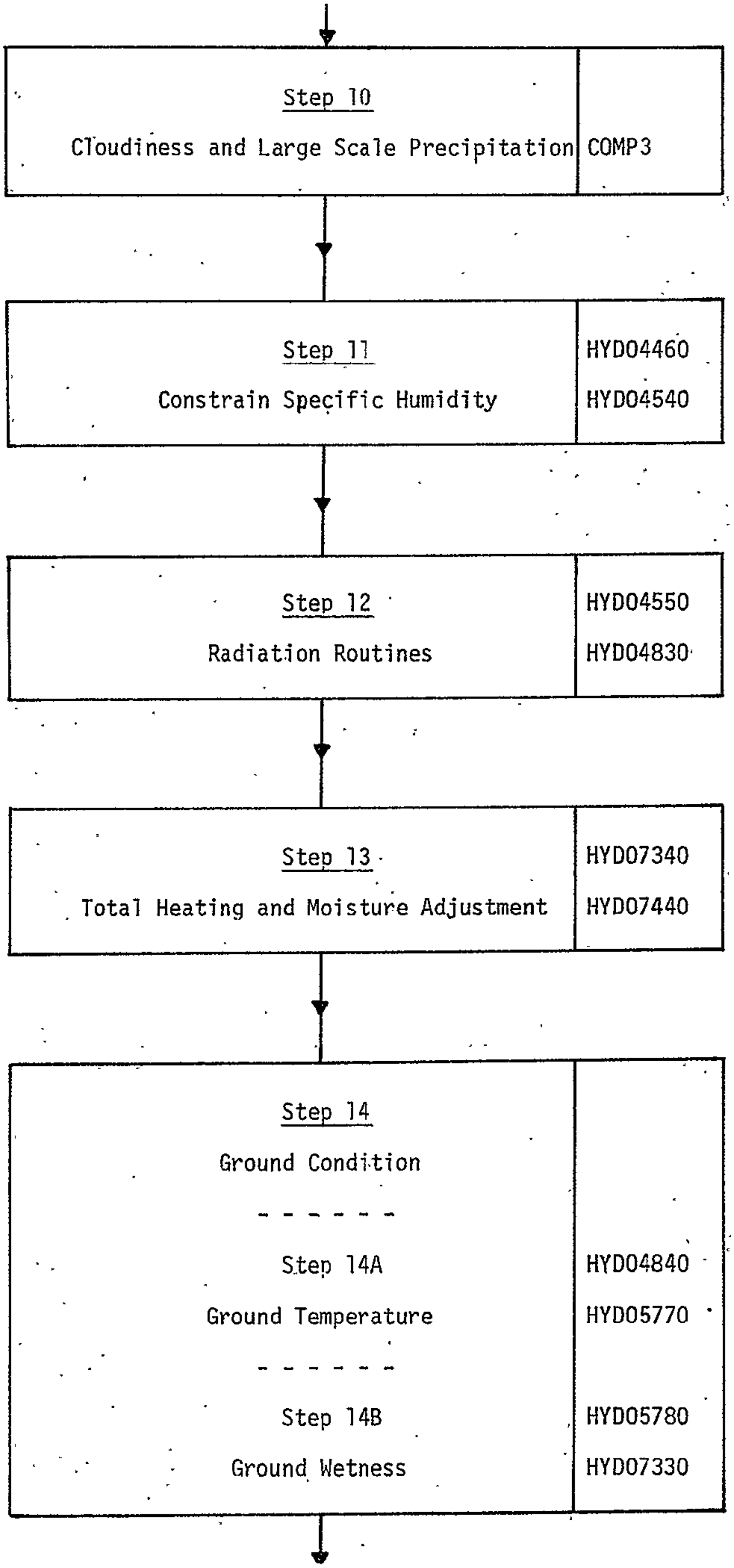


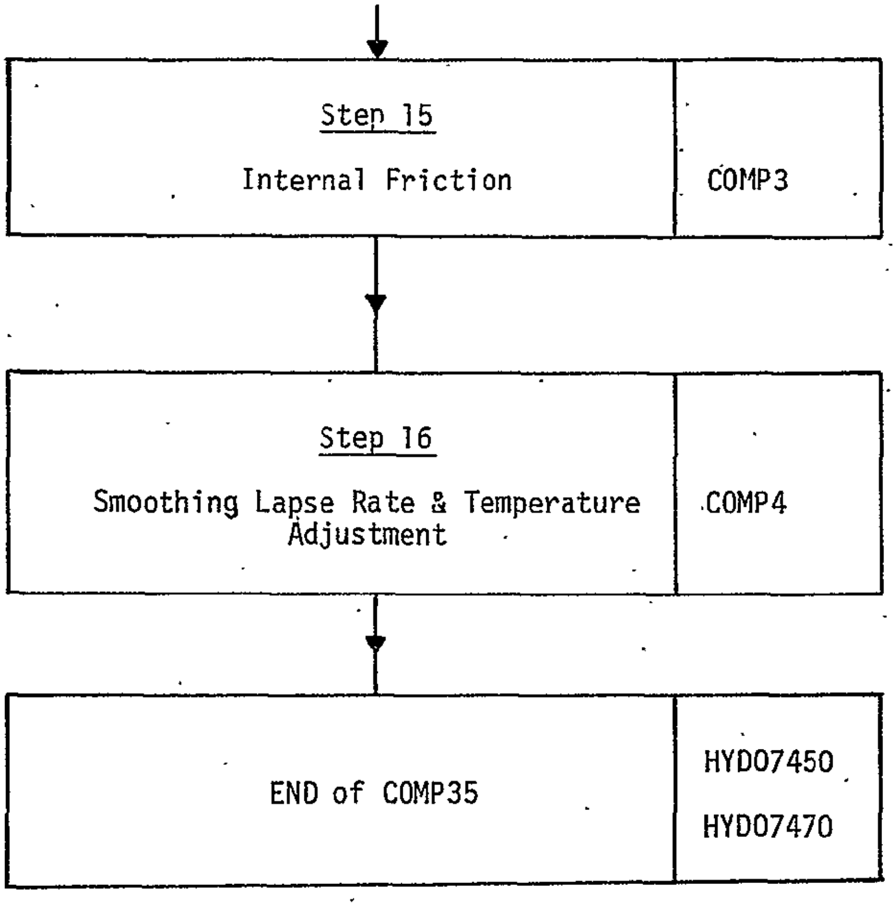

Step 4
Set Up Vertical Arrays for Some Variables
Step 4A
Pressures
HYD01680
HYD01770
Step 4B
Temperature & Convective Adjustment
HYD01780
HYD01930
Step 4C
Moisture Variables
HYD01940
HYD02000
Step 5
Vertical Diffusion of Heat & Moisture
HYD02170
HYD02420
Step 6
Saturation Specific Humidity and Specific Humidity
HYD02430
HYD02480
Step 7
Determination of Surface Temperature and Specific Humidity
HYD02490
HYD03960


Step 8
Contributions of Source Terms at Level Nlay
Step 8A
Sensible Heat & Evaporation
HYD03970
HYD04160
Step 8B
Surface Skin Friction
HYD04170
HYD04450

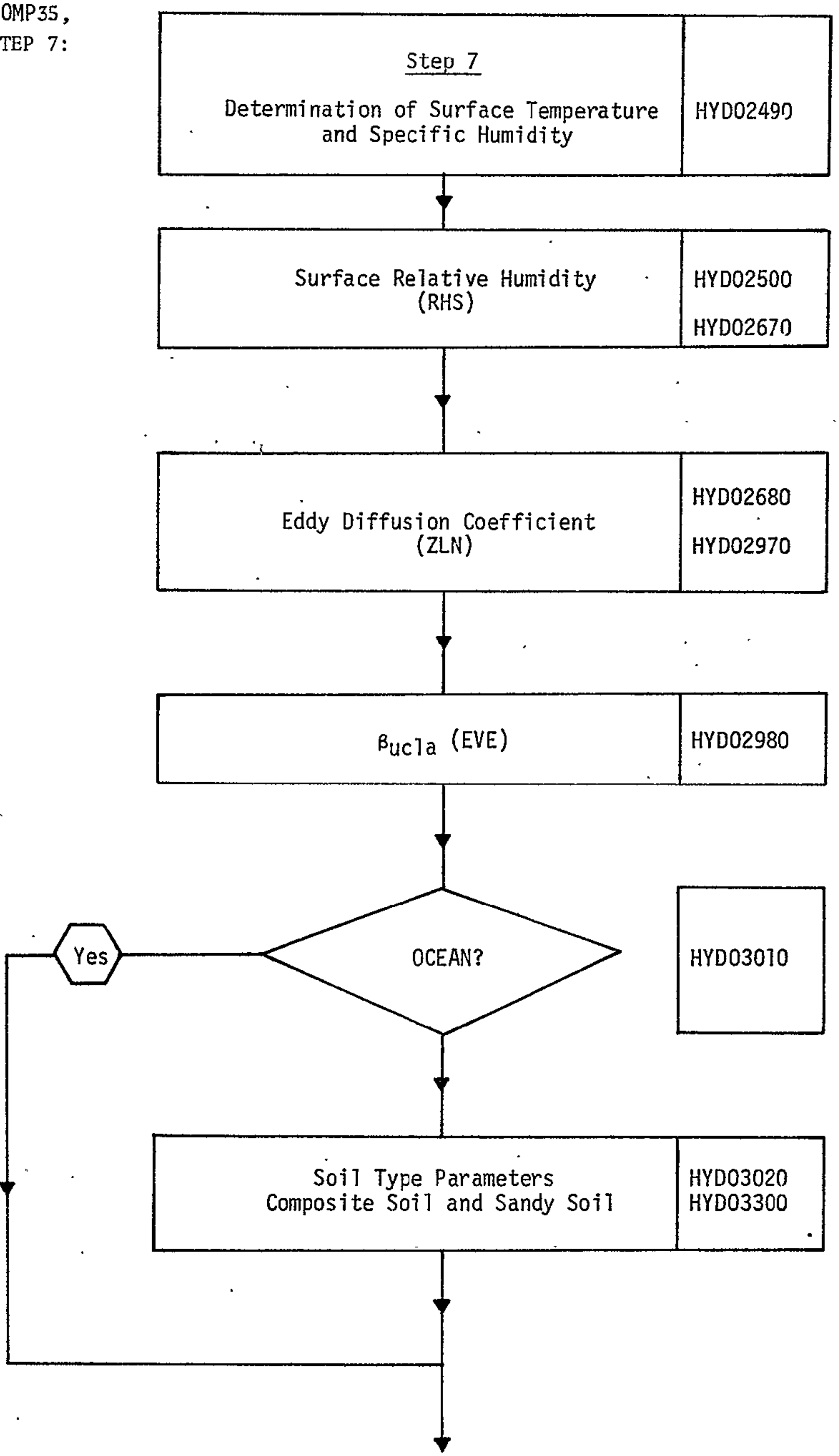


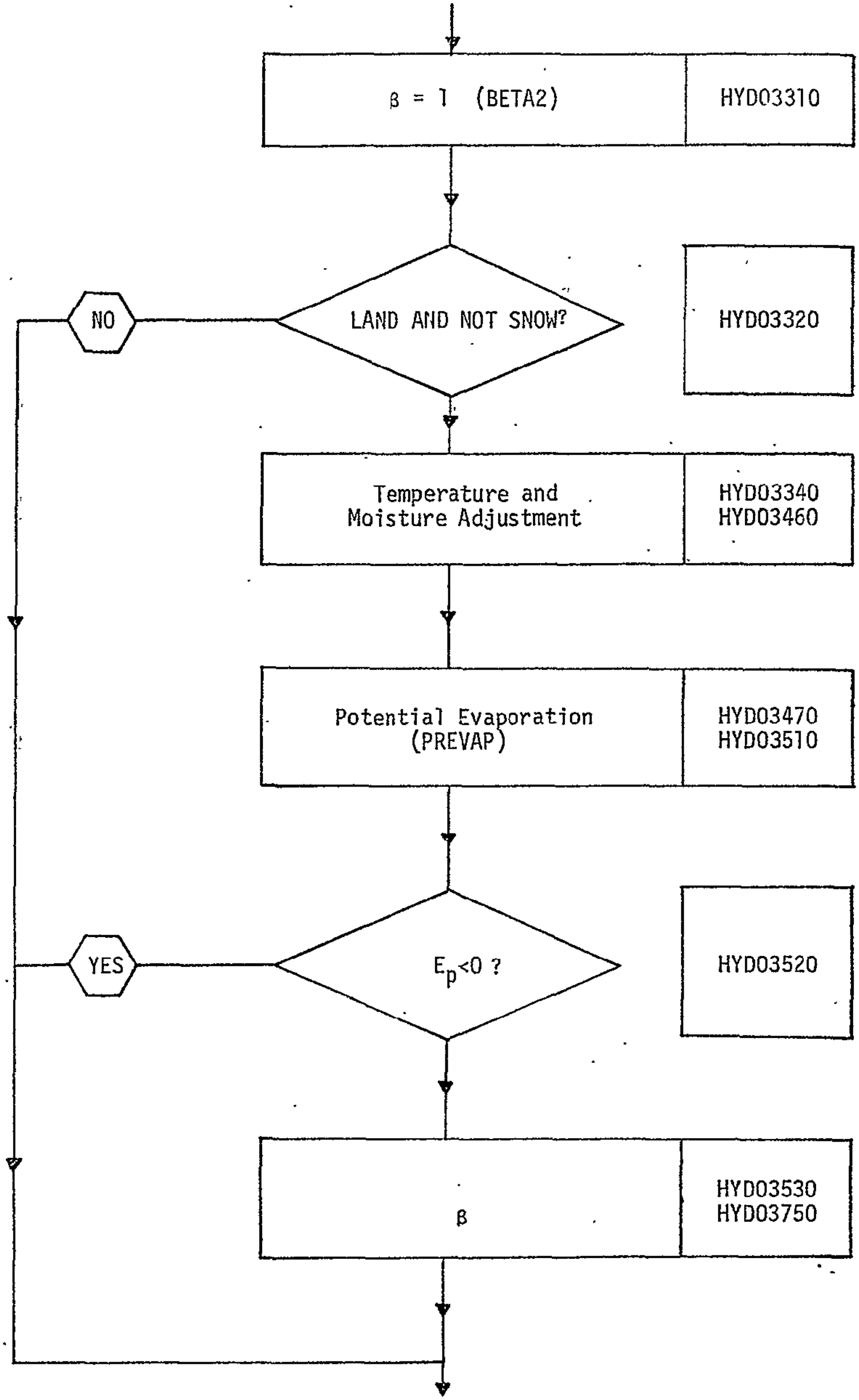
Step 9 Moist Convection	
Step 9A Preparation for Moist Convection	COMP3
Step 9B Vertical Advection of Moisture	COMP3
Step 9C Constrain Specific Humidity	HYD02010 HYD02080
Step 9D Special Moist Convection for 9 Level Model	COMP3
Step 9E Types of Convection	COMP3
Step 9F Distribution of CVTP and CVQP	COMP3

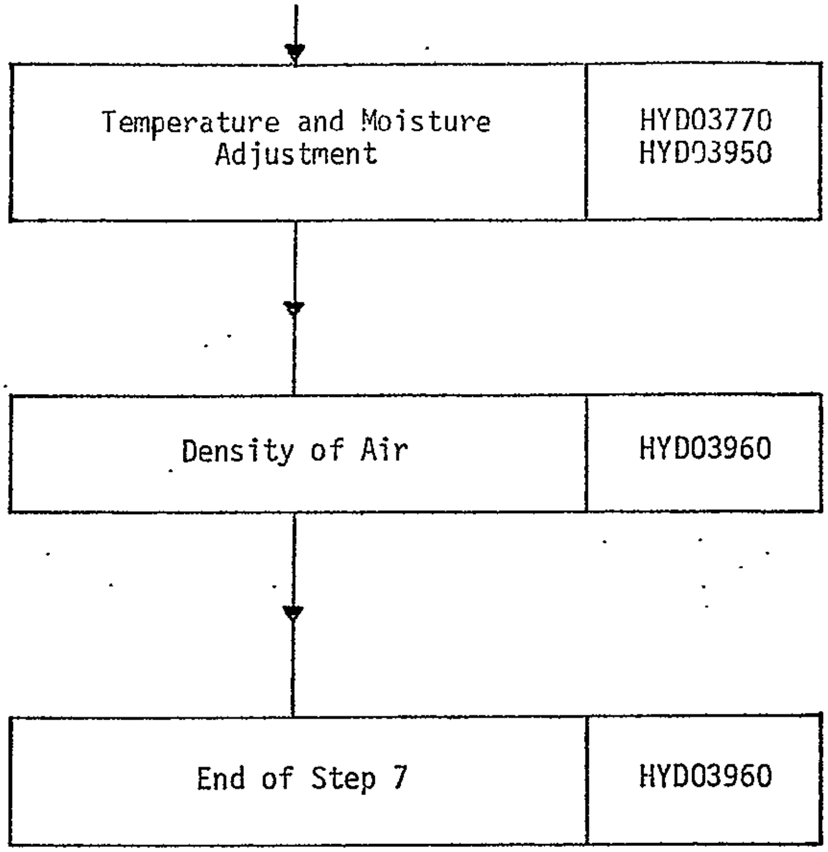

Step 10
Cloudiness and Large Scale Precipitation
COMP3
Step 11
Constrain Specific Humidity
HYD04460
HYD04540
Step 12
Radiation Routines
HYD04550
HYD04830
Step 13
Total Heating and Moisture Adjustment
HYD07340
HYD07440
Step 14
Ground Condition
Step 14A
Ground Temperature
HYD04840
HYD05770
Step 14B
Ground Wetness
HYD05780
HYD07330


Step 15
Internal Friction
COMP3
Step 16
Smoothing Lapse Rate & Temperature Adjustment
COMP4
END of COMP35
HYD07450
HYD07470

COMP35,
STEP 7:

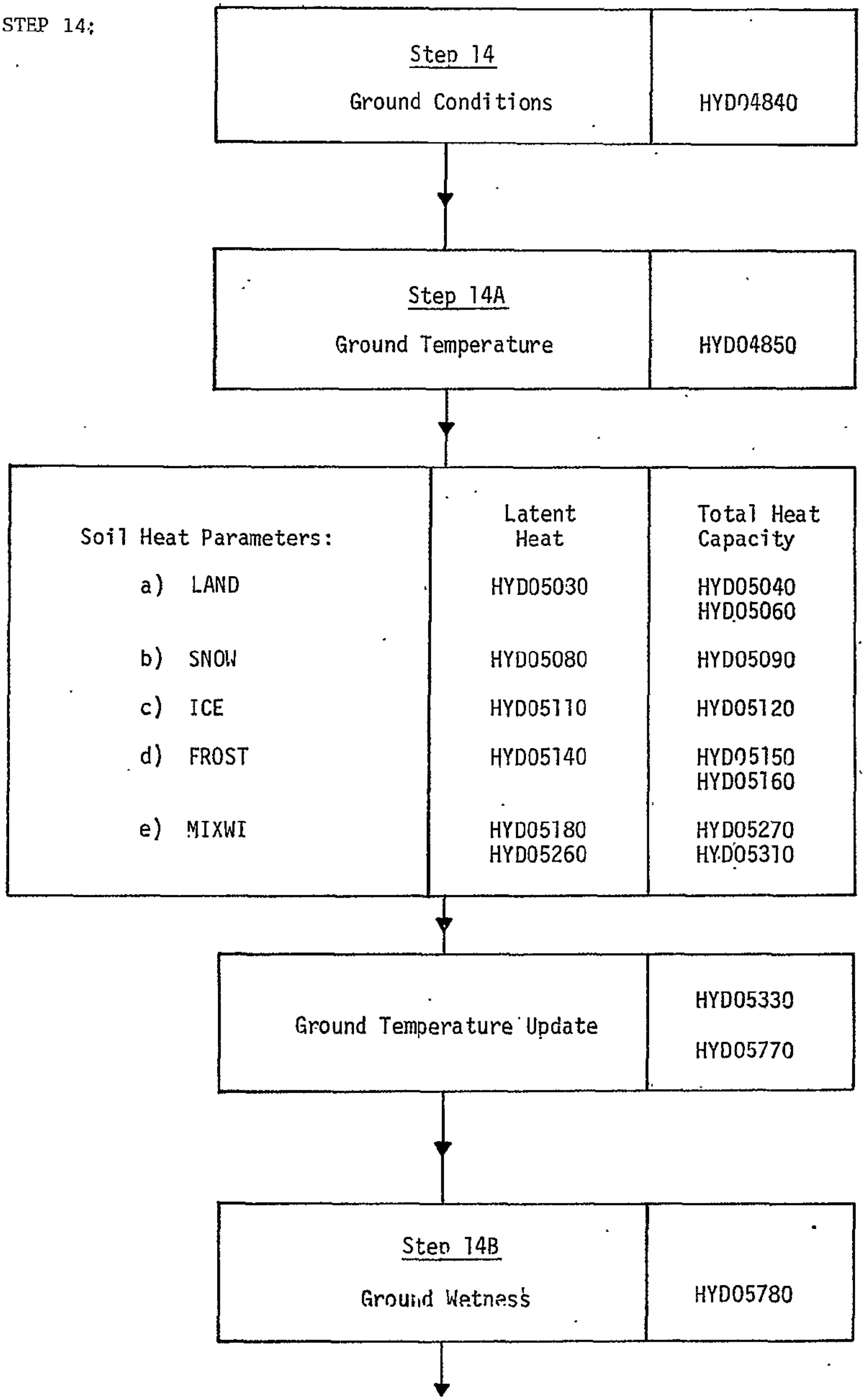



β = 1 (BETA2)
HYD03310
LAND AND NOT SNOW?
HYD03320
NO
Temperature and Moisture Adjustment
HYD03340
HYD03460
Potential Evaporation (PREVAP)
HYD03470
HYD03510
$E_p<0$?
HYD03520
YES
β
HYD03530
HYD03750

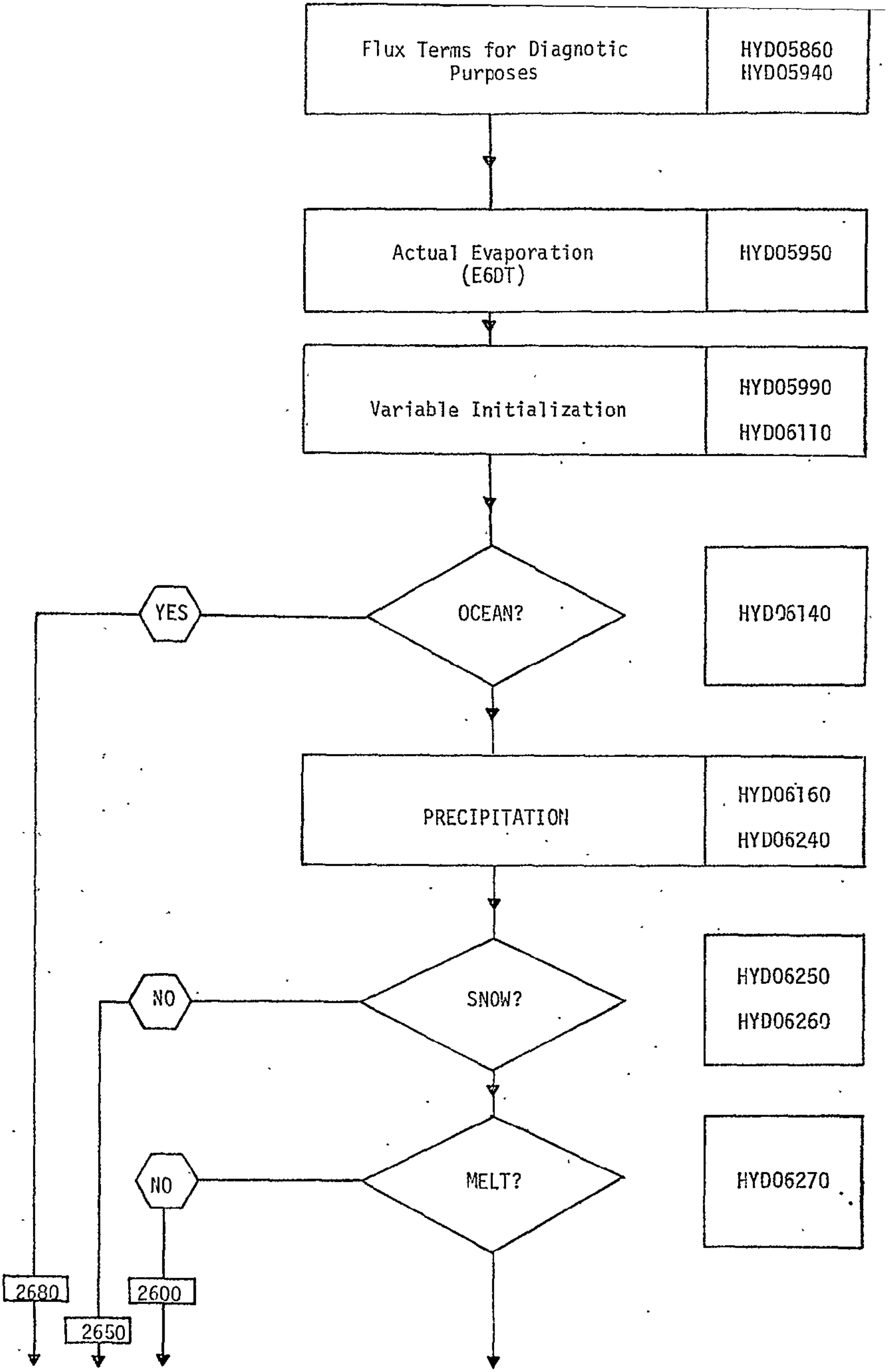

Temperature and Moisture Adjustment
HYD03770
HYD03950
Density of Air
HYD03960
End of Step 7
HYD03960

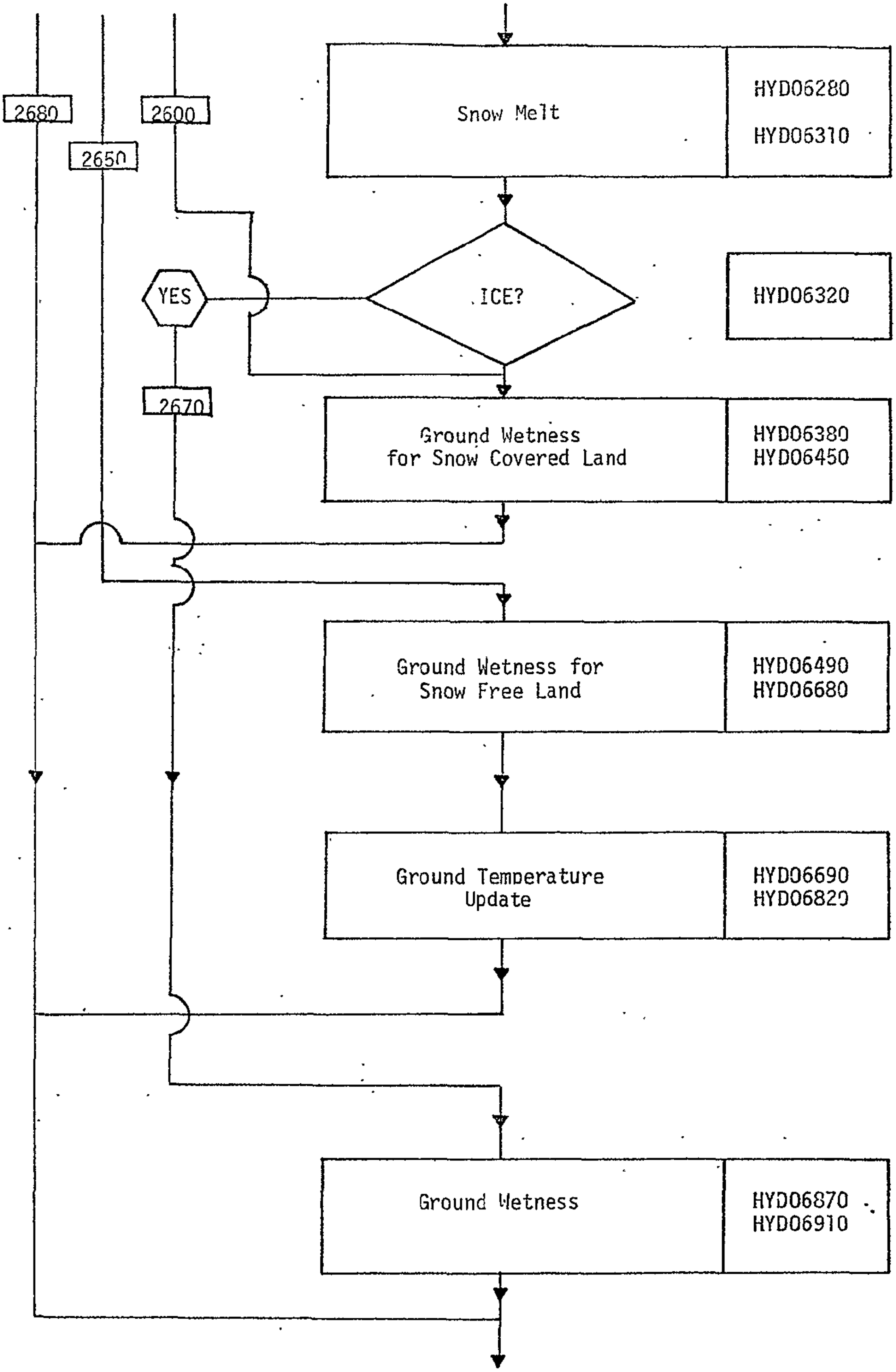
COMP 35,

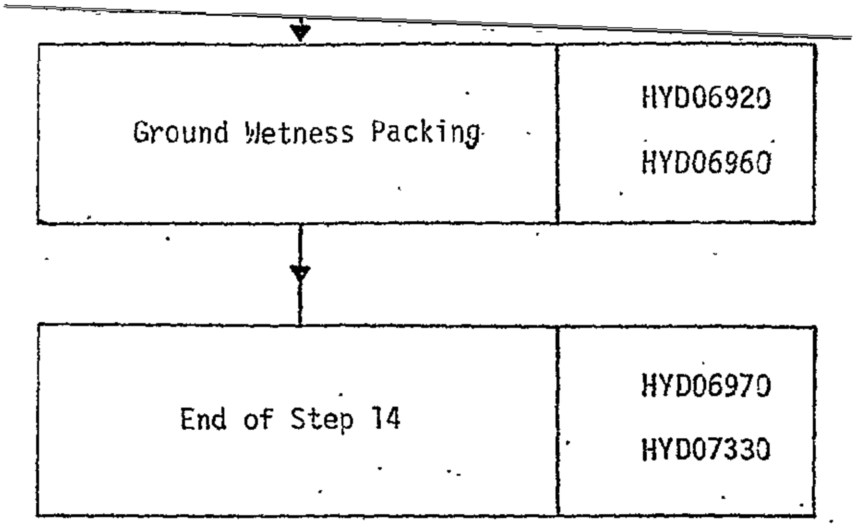
STEP 14;



Soil Heat Parameters:	Latent Heat	Total Heat Capacity
a) LAND	HYD05030	HYD05040 HYD05060
b) SNOW	HYD05080	HYD05090
c) ICE	HYD05110	HYD05120
d) FROST	HYD05140	HYD05150 HYD05160
e) MIXWI	HYD05180 HYD05260	HYD05270 HYD05310


Flux Terms for Diagnotic Purposes
HYD05860
HYD05940
Actual Evaporation (E6DT)
HYD05950
Variable Initialization
HYD05990
HYD06110
OCEAN?
YES
HYD06140
PRECIPITATION
HYD06160
HYD06240
SNOW?
NO
HYD06250
HYD06260
MELT?
NO
HYD06270
2680
2650
2600


2680
2650
2600
Snow Melt
HYD06280
HYD06310
YES
ICE?
HYD06320
2670
Ground Wetness for Snow Covered Land
HYD06380
HYD06450
Ground Wetness for Snow Free Land
HYD06490
HYD06680
Ground Temperature Update
HYD06690
HYD06820
Ground Wetness
HYD06870
HYD06910


Ground Wetness Packing
HYD06920
HYD06960
End of Step 14
HYD06970
HYD07330

PART II.

MODEL RESULTS & ANALYSIS

IV. Off Line Model (OLM)

Introduction

The OLM provides a simple and efficient way to test various hydrologic parameterizations without the need for extensive simulation time. The hydrologic parameterizations are assembled in a parallel manner in the OLM and given the following identification:

1. UCNI - a first revision by the University of Connecticut,
2. UCLA - the UCLA Model (Arakawa, 1972; Arakawa & Mintz, 1974),
3. GISSJK - Jack Kornfield's work previously referred to as GHM, and discussed in this text.

UCNI was developed because we felt that a hydrologically consistent model using only simple and well-defined parameterizations was needed for evaluating the existing GHM. UCNI represents our first step in developing a physically realistic multi-layered model. Specifically, the following ideas were incorporated into UCNI:

a) soil moisture is defined in fraction of saturation;

b) cell moisture changes are calculated from (2-1-1a) with respect to the amount of water at saturation;

c) saturation moisture content is a function of given layer depth and porosity of soil type;

d) the initial soil moisture range is linearly scaled between field capacity (FC) if the surface relative humidity (r_s) equals 100% to permanent wilting point if r_s equals 0;

e) available soil moisture is the difference between FC and PWP;

f) evaporation scaling factor, β, varies from unity at FC to 0 near PWP, with plant factor (2-1-11) kept constant at unity regardless of solar angle; and

g) vegetation and soil type may change effective soil layer thickness.

The OLM reads an output or data tape from a previously run GCM experiment with a certain known ground hydrology model. The ground hydrology parameterization generally used in GCM experiments to develop the data tape has been described in TK. Recalling these parameterizations we see the following:

1. $\beta = \mathrm{Min}(1, 2w')$,
2. $0 \leq w' \leq 1$,
3. WGM = 10 g, and
4. w' = initial w' for all time = WET.

The data set the OLM reads every half hour from the GCM data tape is:

1. TAU, the model time in [hr];
2. PC, the surface pressure in [mb];
3. TSC, the surface temperature in [°K];
4. SHSC, surface specific humidity [g/g] for first time step the net radiation in [ly/day] for 2 through n time steps;
5. GTC, the ground temperature in [°K];
6. GWC, the ground wetness in [% saturation ÷ 100];
7. UC, the x component of velocity in [m/sec] for levels 7, 8, 9;
8. VC, the y component of velocity in [m/sec] for levels 7, 8, 9;
9. TC, the temperature of air in [°K] for levels 7, 8, 9 ; and
10. SHC, the specific humidity in [g] of water vapor/[g] of air for levels 7, 8, 9 .

The ground hydrology model being evaluated calculates the following diagnostic parameters:

1. GW, the ground wetness in [% saturation ÷ 100];
2. TS, the surface temperature in [°K];
3. GT, the ground temperature in [°K]; and
4. AET, (formerly E6DT) the evapotranspiration flux in [cm/hh].

With the GCM data tape and subroutines SDET (Solar angle calculation), SURFWD (Surface wind calculation), and RITE (Diagnostic parameters) the OLM simulates an on-line run and calculates the diagnostic variables. At the end of the experiment comparisons between GW, GWC, TS, TSC, GT, GTC and AET, AETC (from UCLA) were made and will be discussed in a later section.

The OLM-UCLA1 and OLM-UCLA2 were incorporated in OLM to calculate the AET flux (actual evapotranspiration, missing on data tape) for the case of variable ground wetness (GW≠K, OLM - UCLA1) and constant ground wetness (GW=K, OLM - UCLA2). The recalculation of AETC was also necessary because of the different eddy diffusivity parameterizations used in developing the GCM data tape versus OLM. The TK eddy diffusivity paramterization was used in off-line experiments because it required a substantially smaller data set.

In figure 4-1 a schematic is presented of the parallel hydrology parameterizations in the OLM. The accuracy of the OLM in simulating an on-line calculation can be evaluated by comparing UCLA(GW = K) with OLM-UCLA1 or OLM-UCLA2. Close agreement between UCLA and OLM-UCLA2 was always found. In particular, Table 4-1 outlines how diagnostic variable comparisons are made for the different hydrologic parameterizations.

GCM with UCLA Formulation and NCAR Eddy Diffusivity (EDNS)

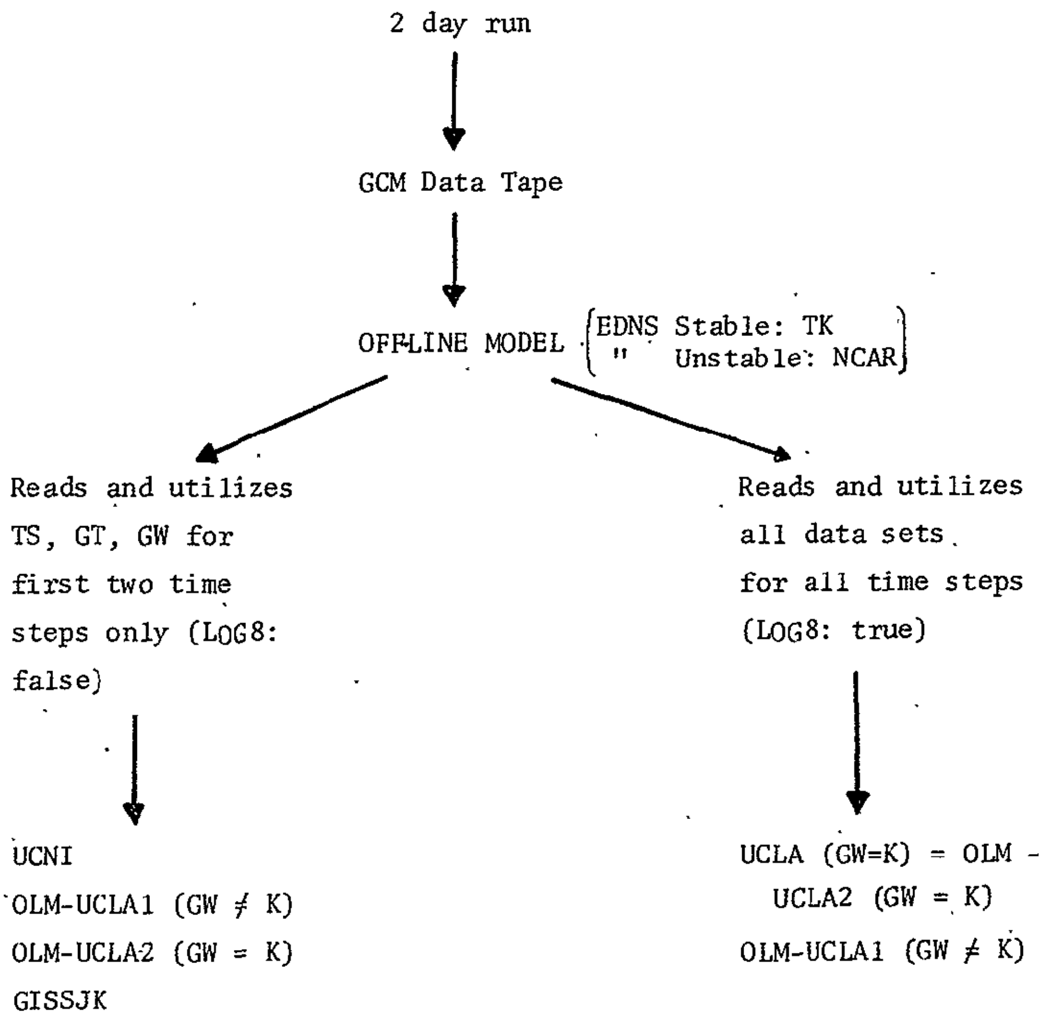


FIGURE 4-1 Schematic of Parallel Model in OLM

TABLE 4-1

Model Diagnostic Parameter Read and Calculation Scheme

GCM Data Tape Variables OLM Models		TSC	TS	GTC	GT	GWC	GW	AETC	AET
UCNI		R	C		C		C		C
OLM-UCLA1: UCLA w/GW Variable	LOG8:F	R	C		C		C		C
	LOG8:T	R	C	R	C	R	C	C	
OLM-UCLA2: UCLA w/GW Constant	LOG8:F	R	C		C		C		C
	LOG8:T	R	C	R		R	C	C	
GISSJK		R	C		C		C		C
UCLA: GCM Data Tape (LOG8:T) Values w/GW Constant		R		R		R		C	

R: Model reads data tape variable every time step

C: Model calculation of this variable will be used for diagnostic purposes

It should be noted that the surface and ground temperature are calculated by the following different schemes:

$$TSC^N \rightarrow TS^{N+1},\ TSC^{N+1} \rightarrow TS^{N+2} \ldots \text{etc.}$$

$$GTC^N \rightarrow GT^{N+1} \rightarrow GT^{N+2} \rightarrow GT^{N+3} \ldots \text{etc.}$$

Thus, TS differences reflect variations during a time step while GT differences represent cumulative effects since second data tape read.

Differences in Hydrologic Parameterizations

In order to understand the significance of the comparisons discussed later we will highlight their differences in this section. First, the UCNI differs from the UCLA parameterizations in the following areas:

a) initialization of GW,

b) approach taken in scaling β as a function of GW,

c) soil water content at saturation, and

d) definitions of GW and how it changes.

Secondly, the GISSJK parameterization differs from UCNI in the same areas, a) through d) plus the following:

e) plant factor (effect of solar radiation on β),

f) volumetric heat capacity, and

g) runout.

Among these differences, the principal factors that lead to significant variations in the estimation of the evaporative flux were β and different definitions of changes in GW. Table 4-2 summarizes the differences between these hydrologic parameterizations (UCNI, UCLA, GISSJK).

TABLE 4-2 Comparisons of UCNI, UCLA and GISSJK Parameterization

			UCNI	UCLA	GISSJK
1. Layer Depth		CS	100 cm	100 cm	4 ft (?)
		SS	50 cm	100 cm	4 ft (?)
2. Porosity		CS	.5	?	?
		SS	.5	?	?
3. Field Capacity [% Saturation/100]		CS	.25	?	.25
		SS	.09	?	.09
4. PWP [% Saturation/100]		CS	.10	?	.10
		SS	.025	?	.024
5. Soil Water Content at Saturation [g/cm^2]		CS	50	66.6	66.4
		SS	25	66.6	4
6. Available Water [g/cm^2]		CS	7.5	10.0	10.0
		SS	1.6	10.0	.2
7. GW Initialization		CS	$\frac{SRH\ (FC-PWP) + PWP}{100}$	$\frac{SRH - 15}{85}$	$.5\left(\left(\frac{SRH-15}{85}\right).3 + .4\right)$
		SS	"	--	$\left(\frac{SRH-15}{85}\right)5.0 + .27$
			[% Saturation/100]	[% Available/100]	[% Saturation/100]
8. Plant (≤ 1)		CS/SS	--	--	Cos z/.2588
9. β (≤ 1) x (Plant = 1)		CS/SS	$\frac{WET-PWP}{FC-PWP}$	2 x GW	Double exponential (see text)
10. C	(GW=0)	CS	C1	C1	$C1/\sqrt{2(.386/.3)}$
[cal cm^{-2} deg^{-1}]	(GW=1)	CS	C2	C2	$C2 \times \sqrt{2}$
	(GW=1)	SS	C2	C2	$C2/\sqrt{3/2}$

TABLE 4-2 Comparisons of UCNI, UCLA and GISSJK Parameterization (cont'd)

		UCNI	UCLA	GISSJK
11. Runoff [g/cm^2]		Rain(.1 + .9$(GW)^{1.5}$)	Rain(.1 + .9$(GW)^{1.5}$)	See Text
Examples:				
Rain = .1 [cm/hh]	GW=0	.01	.01	0
	GW=.5	.042	.042	.05
	GW=1.0	.1	.1	.1
Rain = 1.0 [cm/hh]	GW=0	.1	.1	0
	GW=.5	.42	.42	.45
	GW=1.0	1.0	1.0	.9
12. EDV [$m\ sec^{-1}$]		TK (1973)	NCAR	TK (1973)

Notations: CS: composite soil; SS: sandy soil

SRH: surface relative humidity

EDV: surface layer eddy coefficient

Experiments

To conduct the OLM experiments a 2 day GCM run (DSNAMES: I719/VRM0, VRH0, VRP0, VRR0, 11/76) was executed from which the input GCM data tape variables, discussed in the introduction, were extracted for the general US surface and neighboring ocean cells for levels 7, 8, 9 of the GCM. The ground surface and ocean cells are shown in Fig. 4-2. This compacted or condensed GCM tape information was then read by the OLM for the following cases:

			US	Globe	Area
Cell Types	1.	Dry	(J,I) (4,4)	(J,I) (33,15)	Dry Southwest
	2.	Average	(3,6)	(32,17)	Southern Great Plains
	3.	Wet	(7,12)	(36,23)	Canada/New England

in combination with the following ground hydrology parameterizations:

UCNI
OLM-UCLA1 (GW≠K constant)
OLM-UCLA2 (GW=K constant)
UCLA (GW=K constant)
GISSJK

These experiments took about 1 minute on IBM 360-50 at the University of Connecticut Research Computer Center while the Amdahl at GSFC took about half this time to execute.

Results

The OLM provided a simple comparison of the various ground hydrology parameterizations that were reviewed in this section. In particular, the following parameters are discussed and summarized:

Soil moisture

Surface and ground temperature

Potential & actual evapotranspiration and their ratio, β.

Soil Moisture

The following comparisons were made about soil moisture levels and variations for various cell cases (see Fig. 4-3 to 4-5):

1. GISSJK moisture levels were significantly higher for all three moisture cases;
2. UCNI and UCLA moisture levels were close in all three moisture cases;
3. OLM-UCLA1 (GW≠K) moisture levels changed significantly for typical ET and rain fluxes; and
4. In general the change of moisture levels was not significant during two day test period. (Therefore longer OLM runs of duration greater than 2 days should be made.)

Surface and Ground Temperature

For temperature comparisons the following assessments were made (see Fig. 4-6 to 4-11):

1. The ground and surface temperature calculations for the UCLA model and UCNI were consistent for all cases with better surface temperature agreement during daylight hours;
2. Temperature predictions were generally in phase for most models and cell types with the exception of GISSJK;
3. The ground and surface temperature were generally higher for GISSJK, sometimes as much as 10°C higher for the different cell types; and

4. The ground temperature for GISSJK demonstrated a phase shift of about 3 hours with a gradual upward drift in magnitude from those of other models.

Potential (ET) and Actual (AET) Evapotranspiration and Their Ratio, β.

The OLM provided the following results related to evaporation rates for the three parameterizations (UCNI, UCLA, GISSJK) (see Fig. 4-12 to 4-14 and Table 4-3):

1. Potential evaporation rates were generally highest for GISSJK for all cell types;
2. The potential evaporation scaling factor, β, was lowest for GISSJK and highest for UCLA for all cell types;
3. The actual evaporation rate was lowest for GISSJK for all cell types; and
4. The UCNI generally predicted values of PE and β that appear reasonable when compared with GISSJK and UCLA models.

Summary

The major findings discussed in previous sections individually will now be summarized collectively:

Different definitions of soil moisture, although significant between models, did not cause major differences in the calculation of AET. This suggests a certain consistency within each model.

Surface and ground temperature results are similar for all models for the range of moisture levels tested with the exception of GISSJK.

Ground temperature difference of +10°C between GISSJK and other models is believed to be due to the underestimation of AET by a factor of 2 or more.

Surface temperature variation of 10°C between time steps had appeared to be due to separate (stable, unstable) parameterizations for the surface layer eddy coefficient. The variations had a deleterious effect on AET when they occurred. When the OLM used the eddy diffusivity in TK, the oscillations were greatly reduced.

Peak AET seems to occur when surface and ground temperatures peak at mid-day.

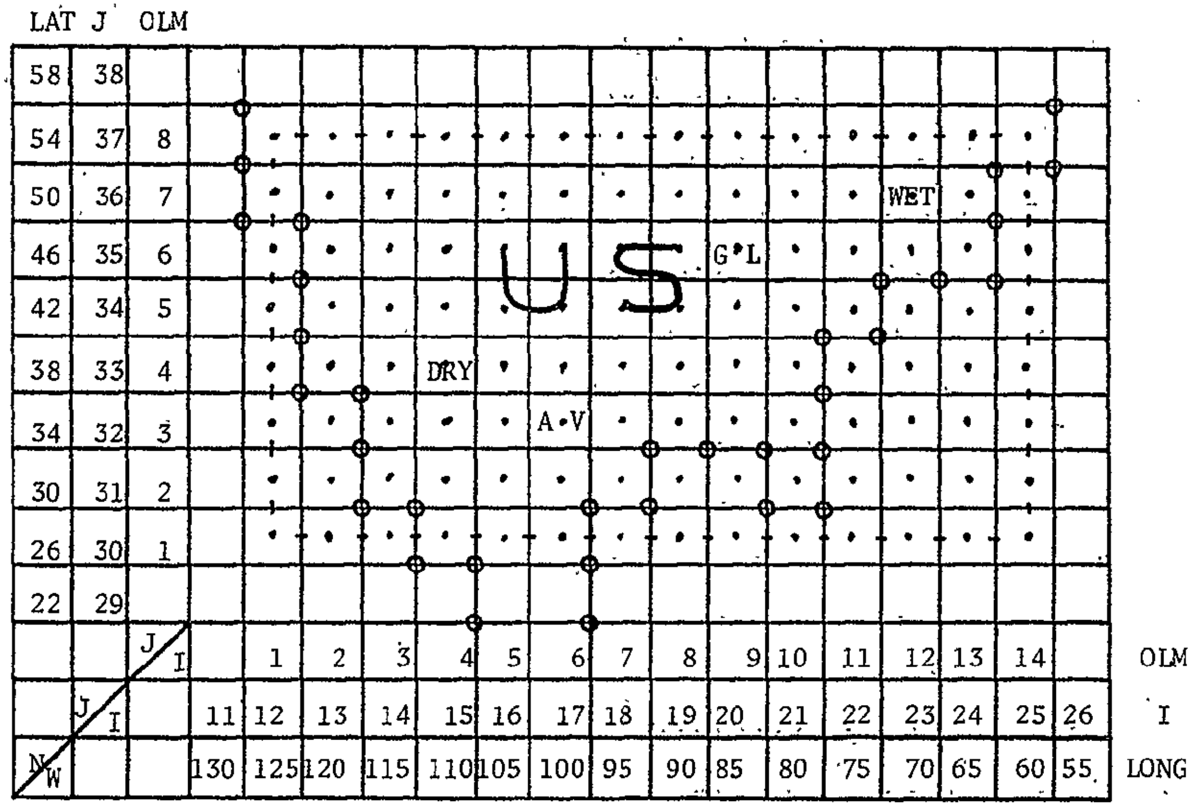
β as a function of PET&GW in GISSJK led to a "flat" - fairly constant AET for most of the daylight hours. β as a function of GW in UCNI & UCLA produced significant variations of AET during daylight hours. In OLM-UCLA1 with variable ground wetness noticeable changes in β occurred during significant evaporation or precipitation periods.

AET estimates for three different soil moisture levels, wet, average and dry case, were remarkably similar in magnitude for the 2 days. This is due to the compensating factors of a large PET when β is small for the dry case or vice versa for the wet case.

Small negative evaporation rates generally occur during evening hours.

UCNI appears to be a reasonable revision of currently available ground hydrology models.

In conclusion the OLM has provided an efficient way to compare three different hydrology parameterizations. The effects of the differences between these parameterizations on soil moisture and temperature, although not interactive with the GCM, can be readily evaluated. The long-term calculations (greater than 2 days) although not attempted at this time should be conducted later as soon as major revisions are completed and a data tape is available.



NOTE: CIRCLES REPRESENT BOUNDARY BETWEEN US LAND MASS AND OCEAN

FIGURE 4-2 OLM CELL LAYOUT AND US LAND MASS

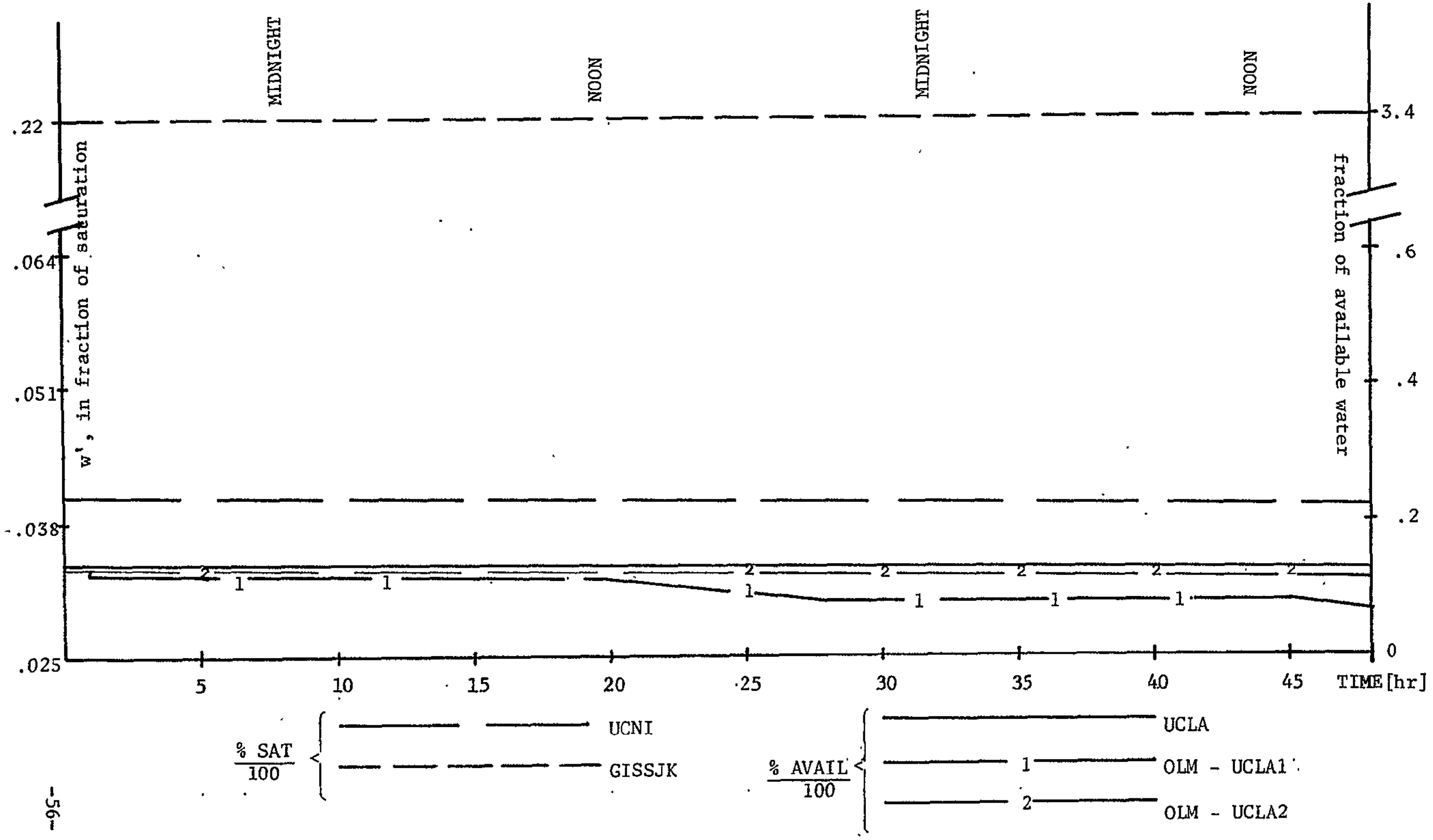


FIGURE 4-3 SOIL MOISTURE CONTENT FOR DRY CELL

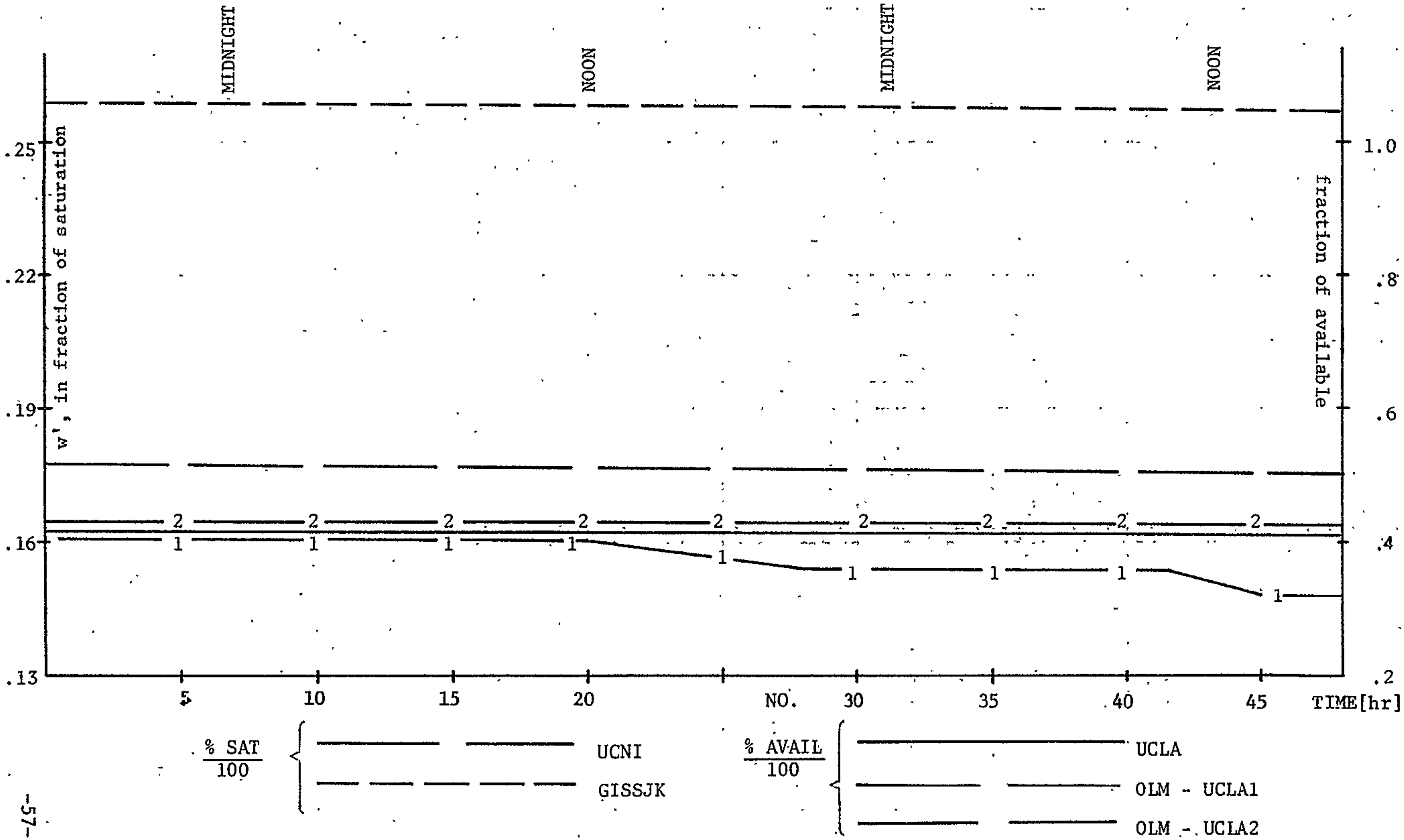


FIGURE 4-4 SOIL MOISTURE CONTENT FOR AVERAGE CELL

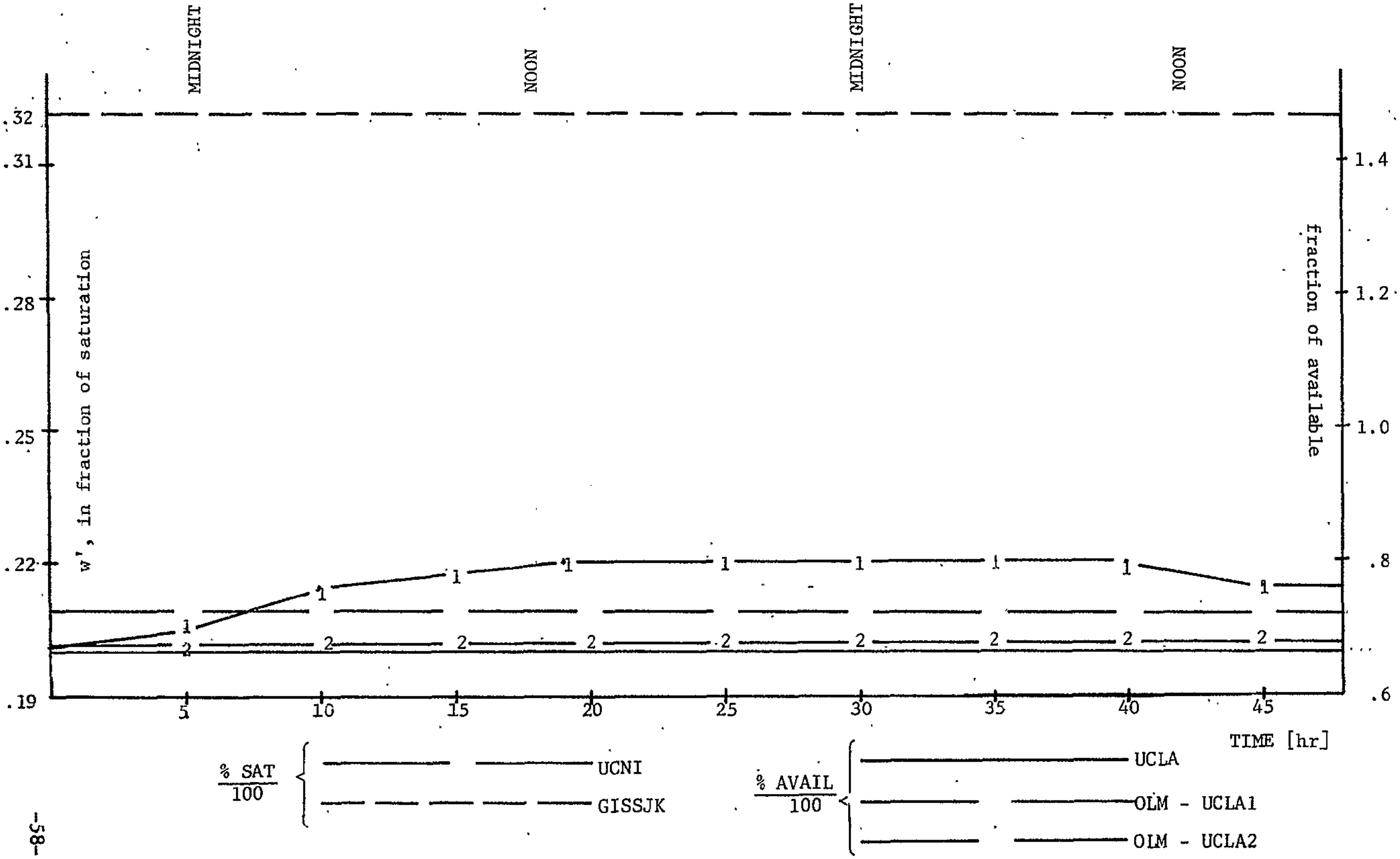


FIGURE 4-5 SOIL MOISTURE CONTENT FOR WET CELL

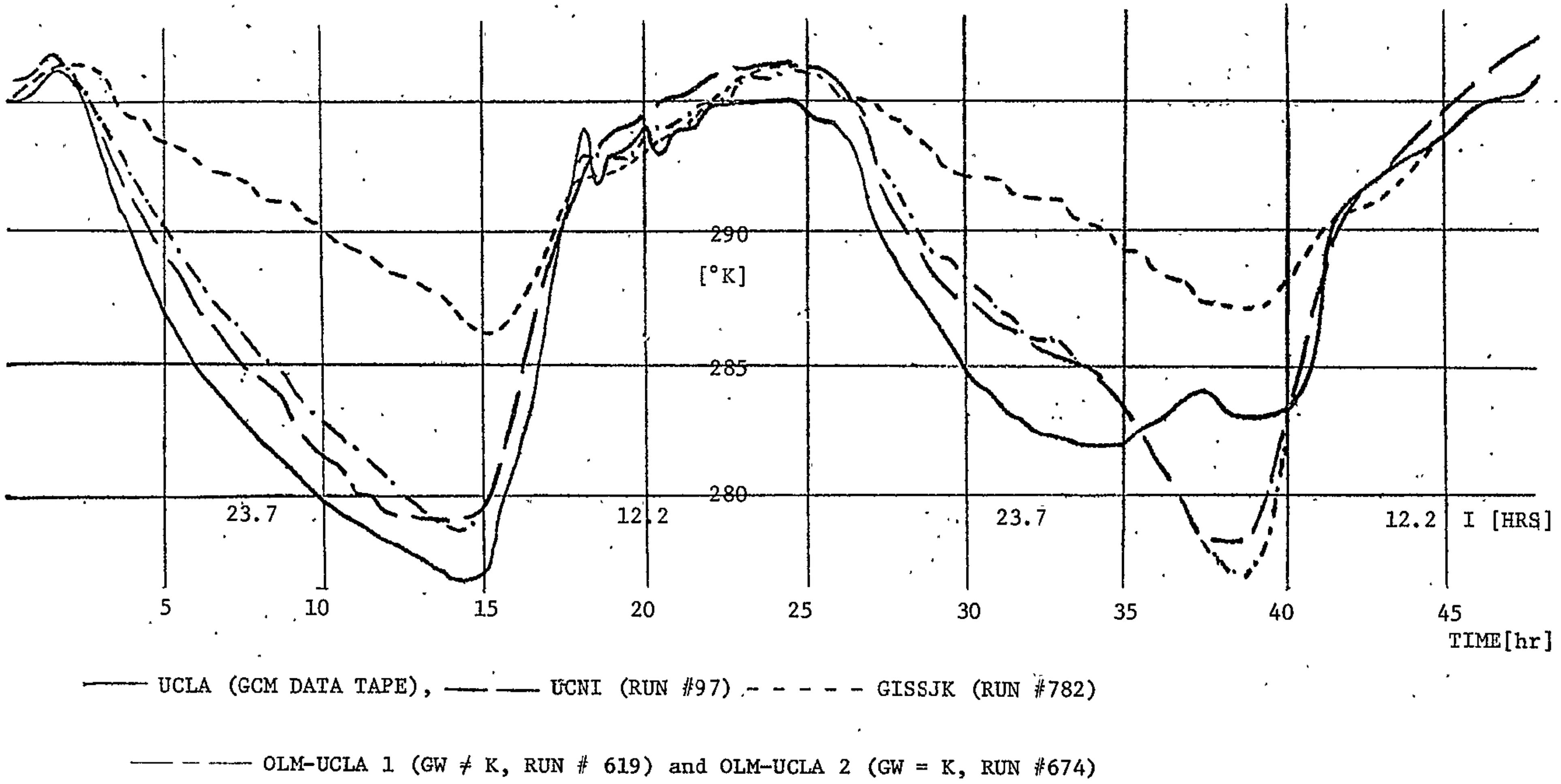


FIG. 4-6 SURFACE AIR TEMPERATURES (TS) FOR DRY CELL

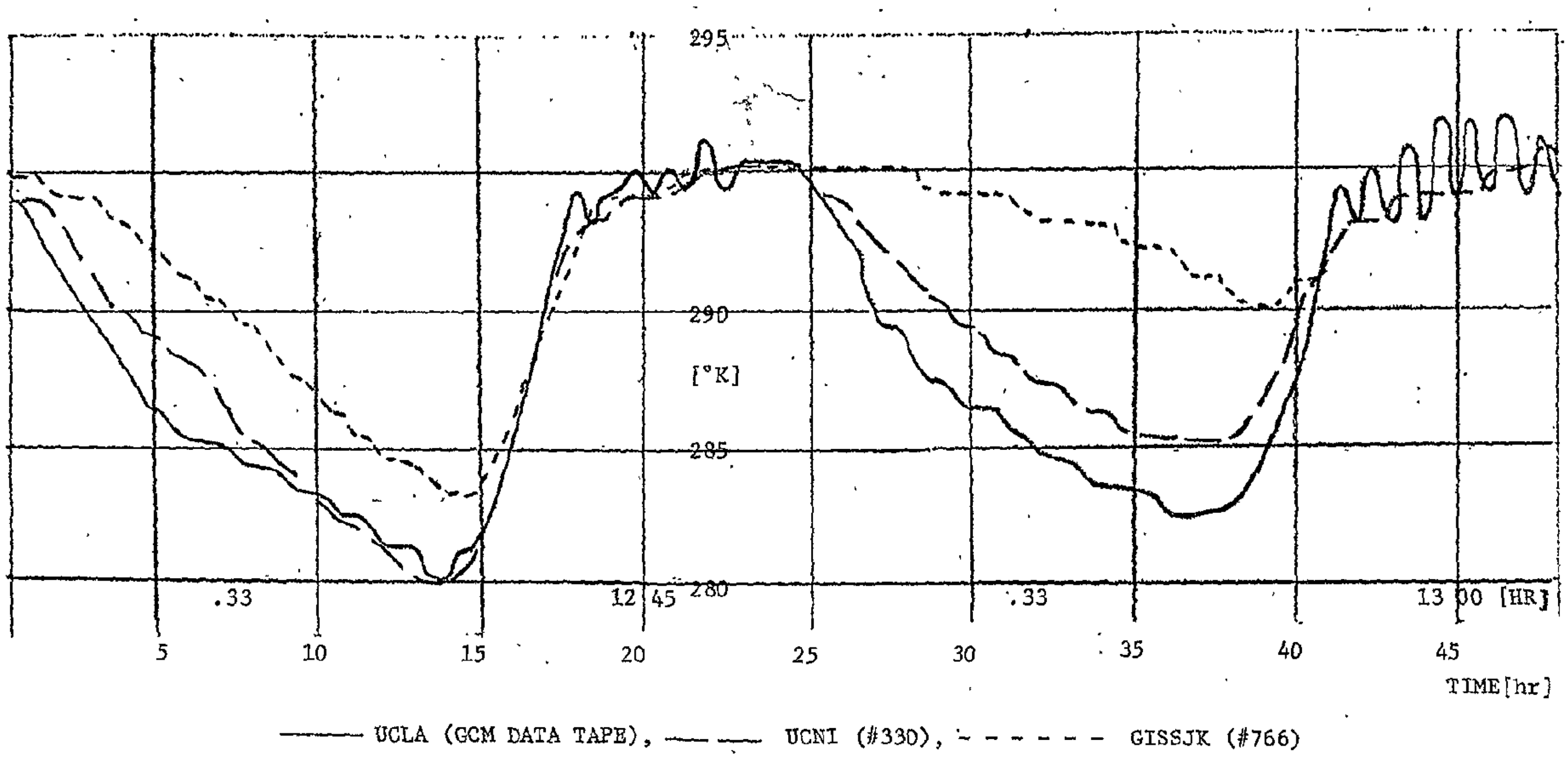


FIG. 4-7 SURFACE TEMPERATURE (TS) FOR AVERAGE CELL

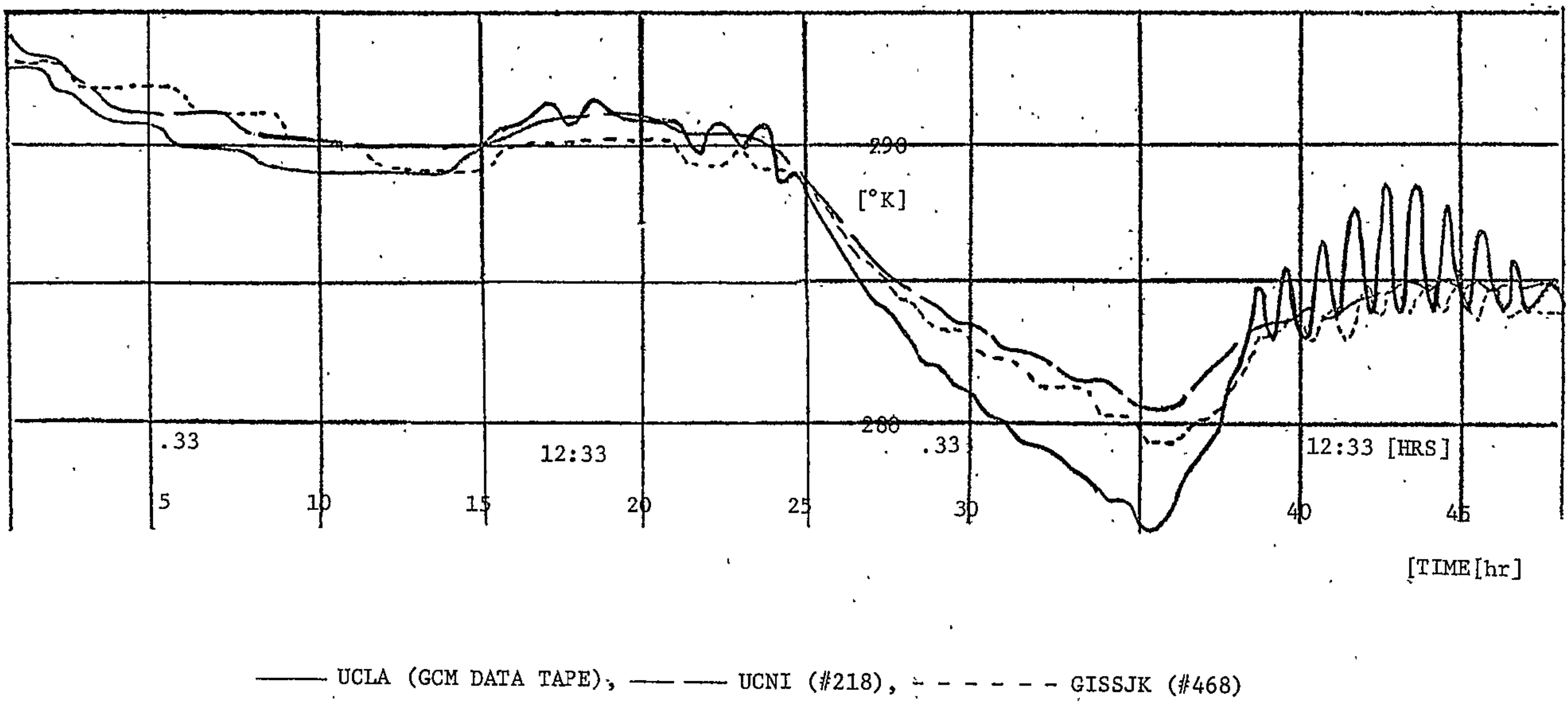


FIG. 4-8 SURFACE AIR TEMPERATURE (TS) FOR WET CASE

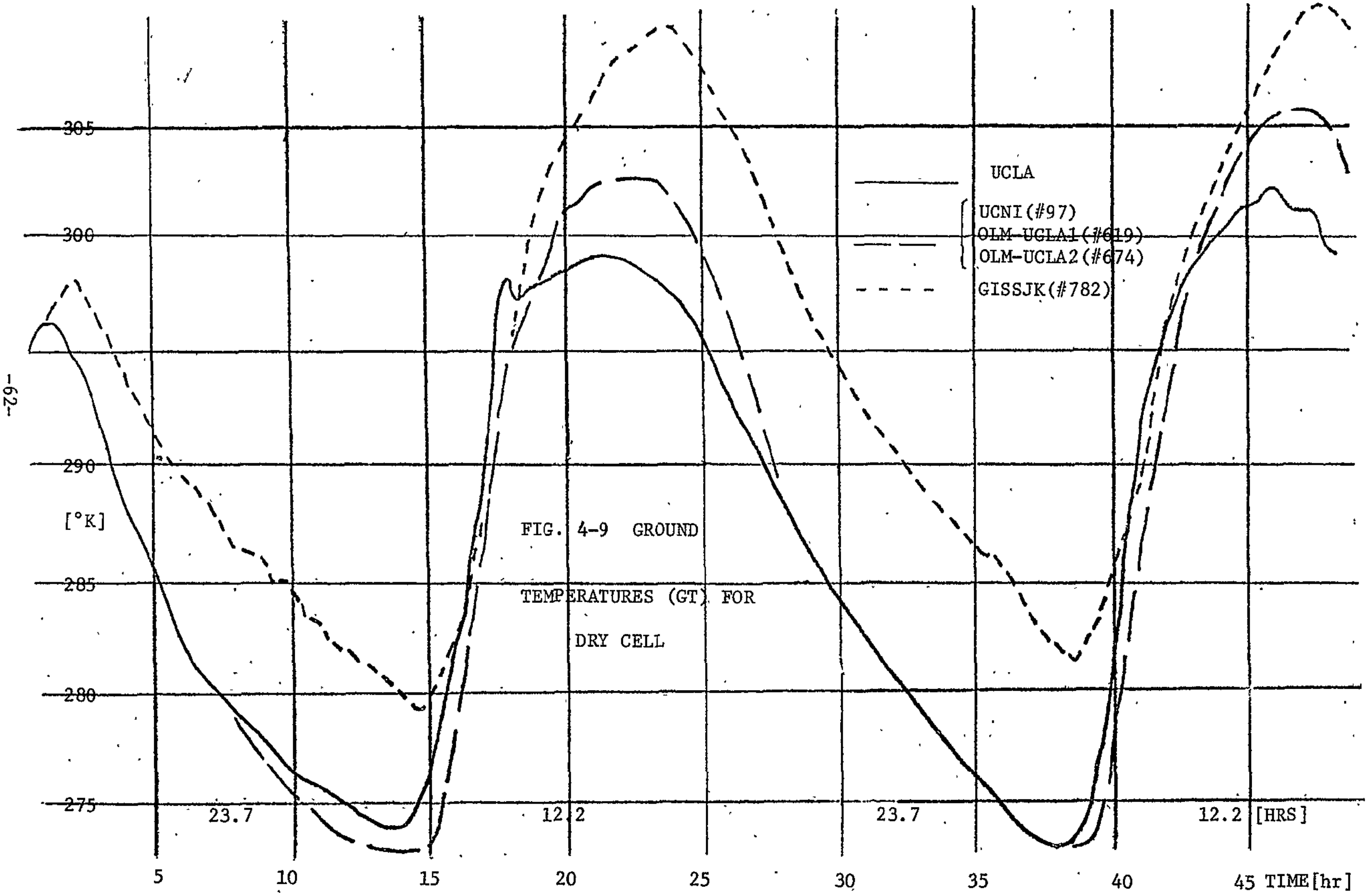
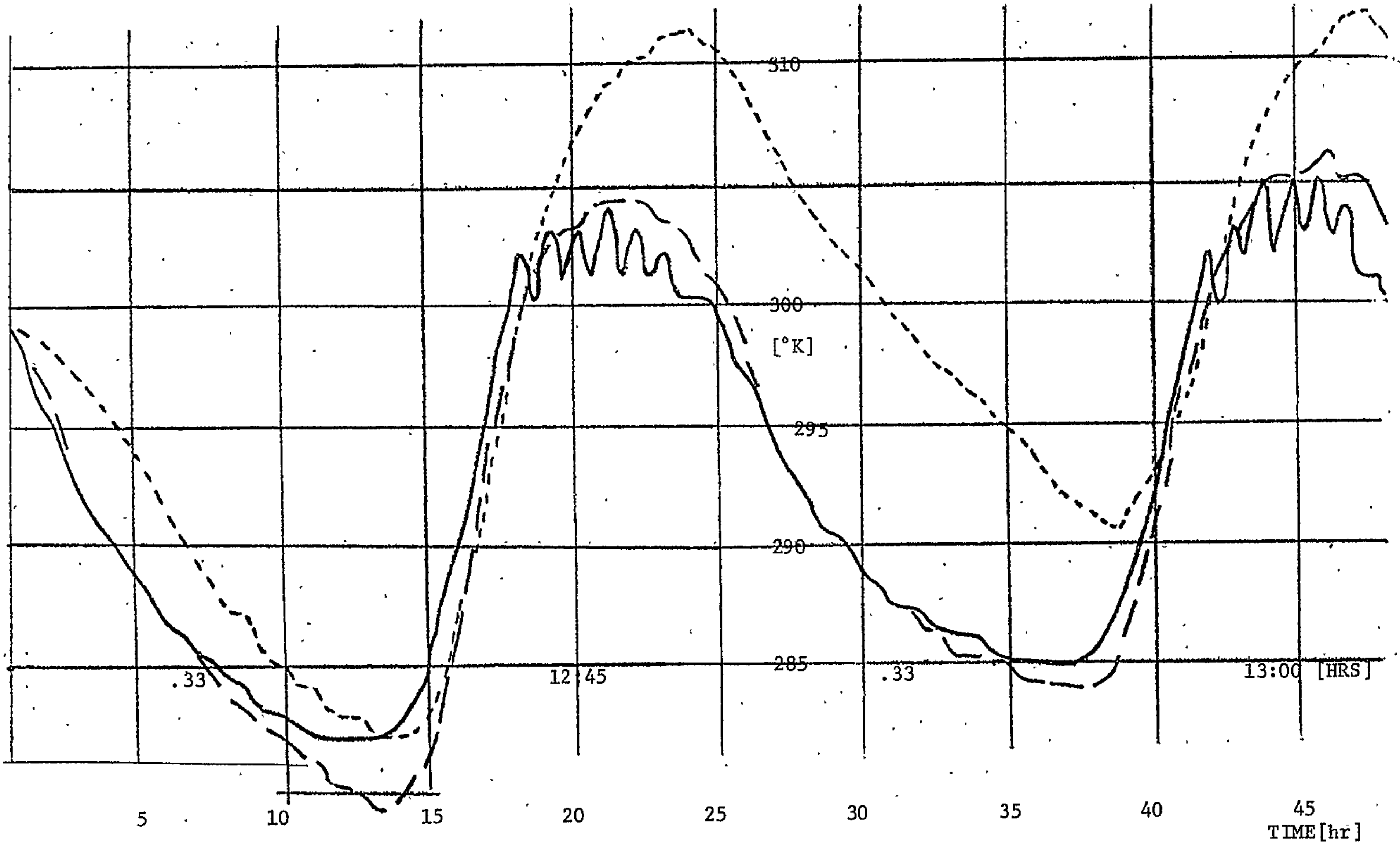


FIG. 4-9 GROUND TEMPERATURES (GT) FOR DRY CELL



——— UCLA (GCM DATA TAPE), —— —— UCNI (#330), - - - - - - - GISSJK (K766)

FIG. 4-10 GROUND TEMPERATURE (GT) FOR AVERAGE CELL

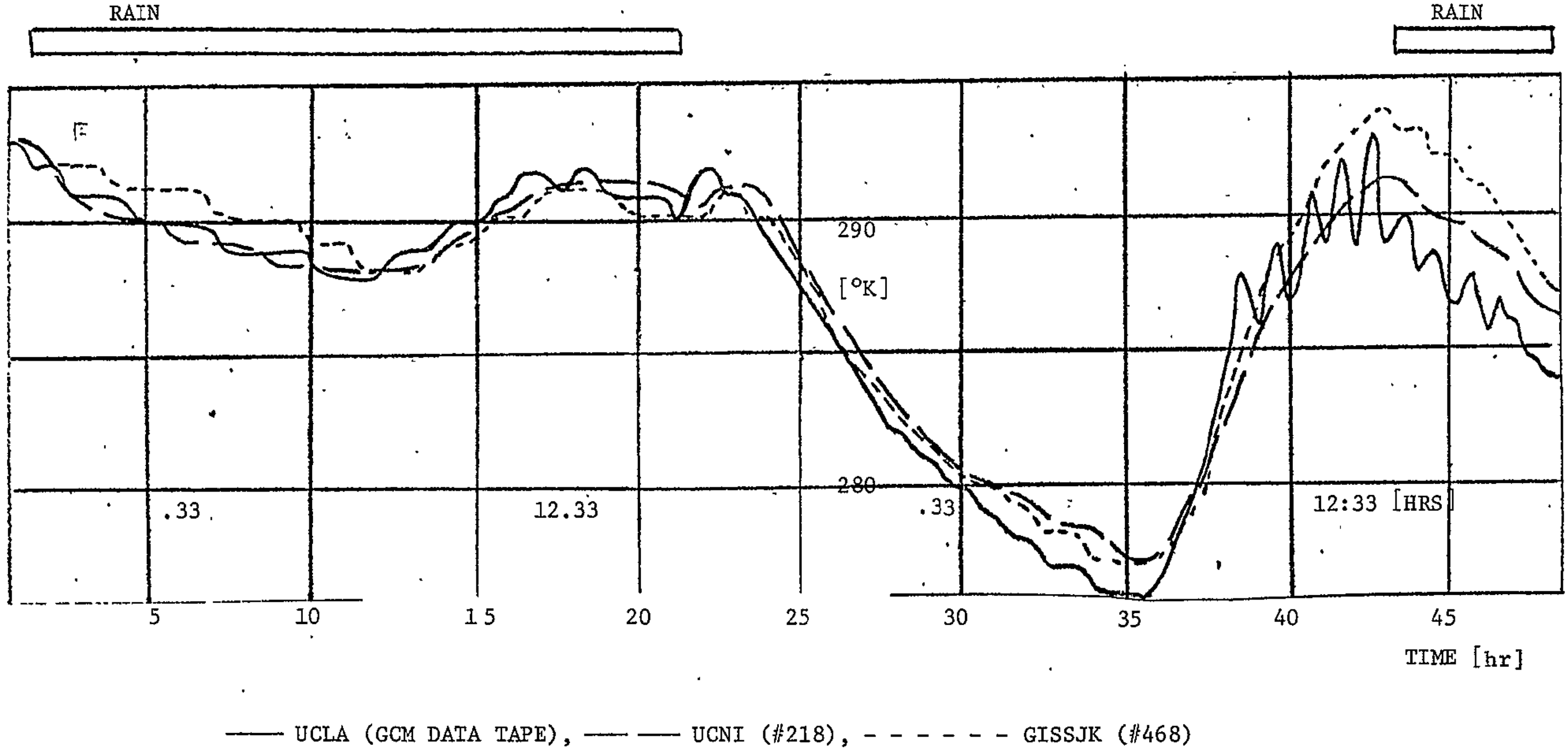


FIG. 4-11 GROUND TEMPERATURE (GT) FOR WET CASE

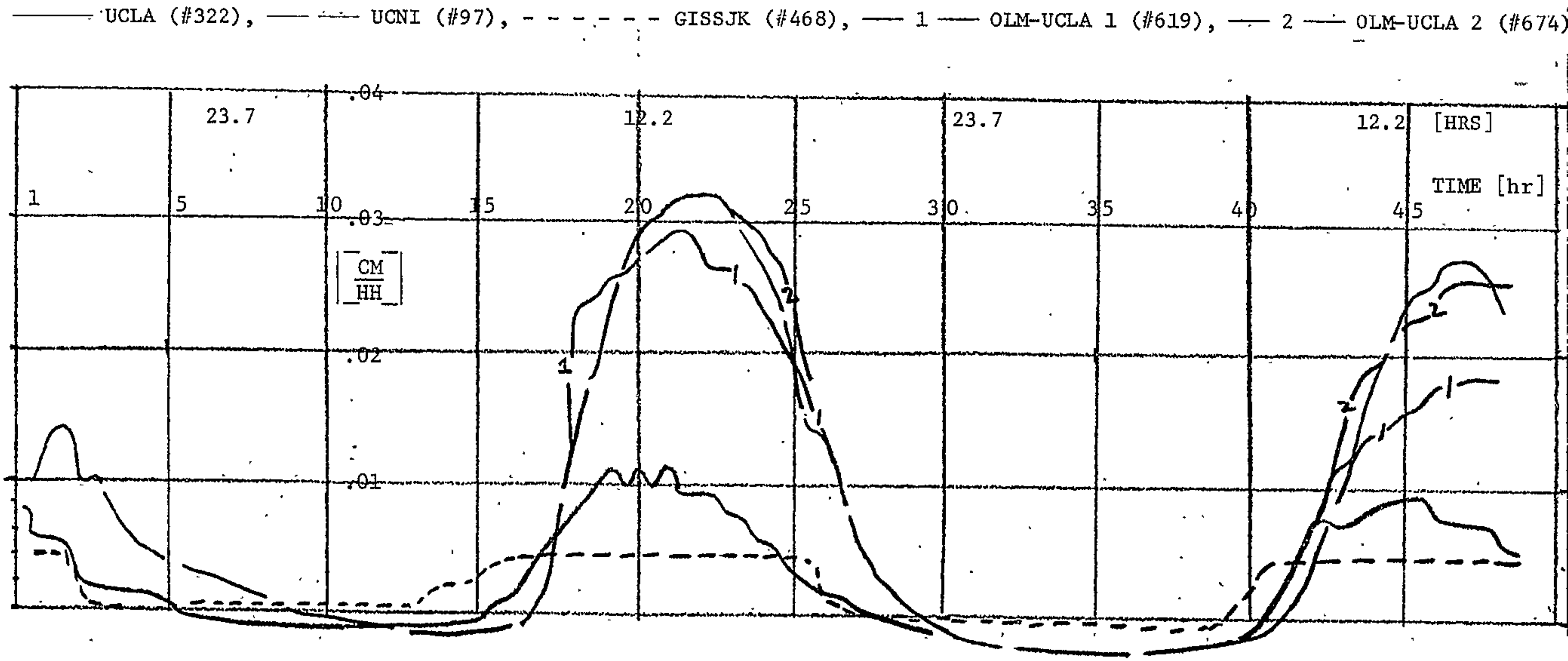


FIG. 4-12 EVAPOTRANSPIRATION FOR DRY CELL

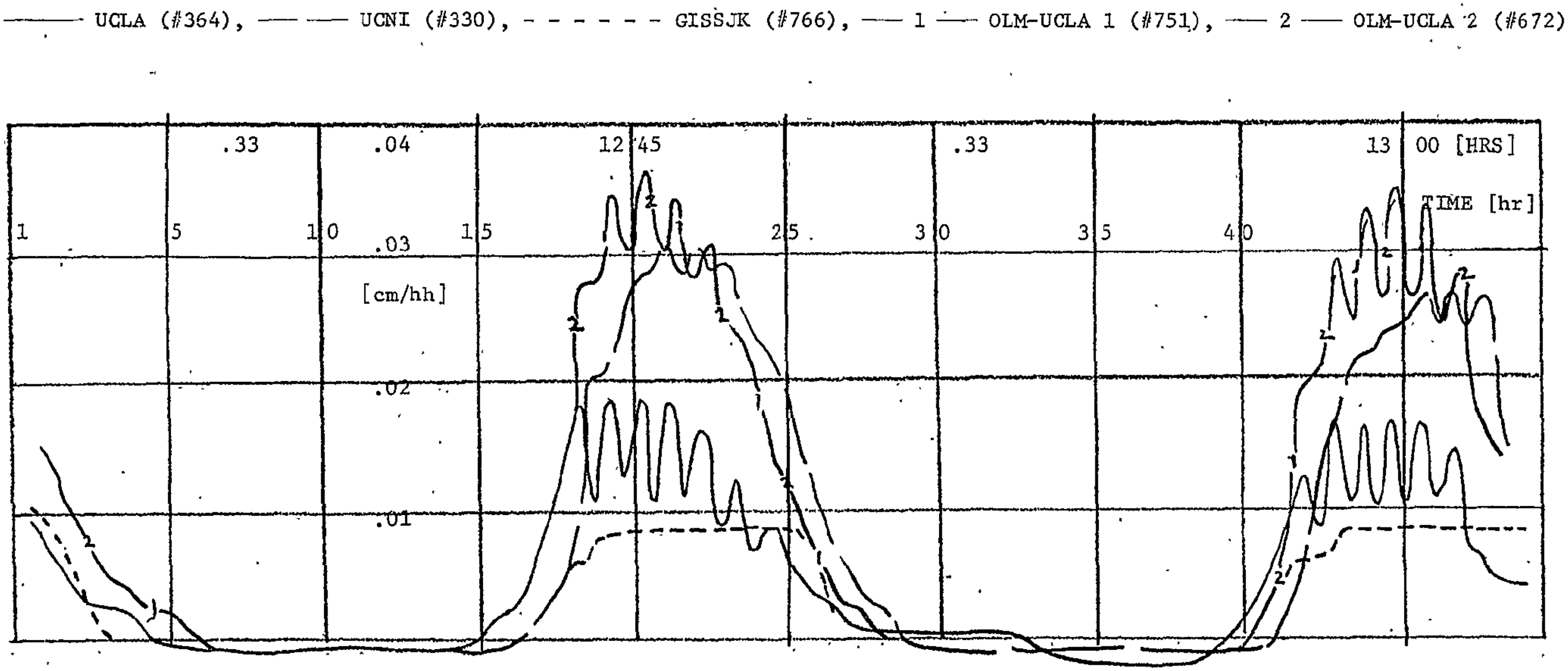


FIG. 4-13 EVAPOTRANSPIRATION FOR AVERAGE CELL

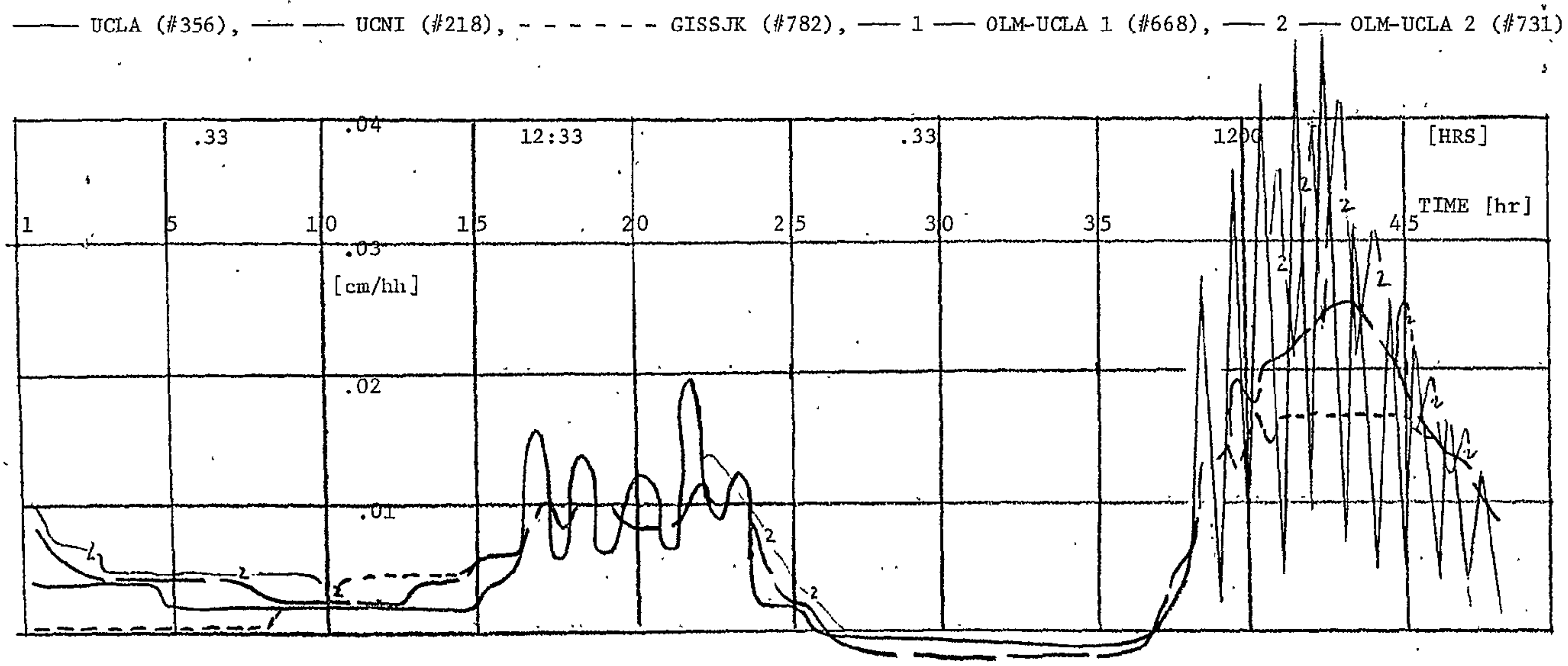


FIG. 4-14 EVAPOTRANSPIRATION FOR WET CELL

CELL	RUN #	MODEL	LOG 8	$\overline{PET} \sim \frac{2}{3} PE_{max}$ $\overline{PET}$ [cm/hh]		$\overline{GW}$ [1] % sat/100 [2] % avail/100		$\overline{\beta}$		$\overline{AET} \simeq \frac{2}{3} AET_{max}$ $\overline{AET}$ [cm/hh]	
				Day 1	Day 2	Day 1	Day 2	Day 1	Day 2	Day 1	Day 2
DRY	97	UCNI	F	.08	.075	.04[1]	.04[1]	.27	.27	.021	.019
	619	OLM-UCLA1	F	.095	.095	.11[2]	.07[2]	.21	.14	.017	.012
	674	OLM-UCLA2	F	.085	.075	.14[2]	.14[2]	.27	.27	.023	.019
	322	UCLA	T	.06	.047	.14[2]	.14[2]	.27	.27	.017	.013
	332	OLM-UCLA2	T	.06	.047	.14[2]	.14[2]	.27	.27	.017	.013
	782	GISSJK	F	.14	.12	.22[1]	.22[1]	.02	.02	.003	.003
AV	330	UCNI	F	.041	.033	.176[1]	.176[1]	.5	.5	.02	.017
	751	OLM-UCLA1	F	.028	.028	.41[2]	.36[2]	.78	.75	.024	.023
	672	OLM-UCLA2	F	.027	.027	.42[2]	.42[2]	.83	.83	.024	.024
	364	UCLA	T	.037	.033	.42[2]	.42[2]	.83	.83	.03	.027
	766	GISSJK	F	.095	.08	.26[1]	.26[1]	.08	.08	.008	.008
WET	218	UCNI	F	.0125	.025	.21[1]	.21[1]	.71	.71	.009	.018
	668	OLM-UCLA1	F	.01	.027	.65[2]	.75[2]	1	1	.01	.027
	731	OLM-UCLA2	F	.01	.02	.65[2]	.65[2]	1	1	.01	.02
	356	UCLA	T	.0125	.025	.65[2]	.65[2]	1	1	.0125	.025
	468	GISSJK	F	.01	.0375	.32[1]	.32[1]	.6	.4	.006	.012

NOTE: % sat/100 = (% avail/100) x (FC-PWP) + PWP

TABLE 4 - 3

DAYTIME AVERAGES OF PE, GW, β AND AET VERSUS DRY, AVERAGE AND WET CELL CONDITIONS

V. Description of the OLM Computer Program

OLM Program

The OLM program contains a main section where parallel hydrologic parameterizations are evaluated. The first two subroutines, SDET and SURFWD provide needed information to the main hydrologic section that would normally be available in a GCM run. The third subroutine, RITE contains the bulk of Fortran statements needed for parameter evaluation.

There is a total of 9 steps in the OLM as illustrated in the flow chart. Through step 2, Parameter Specification, the OLM receives the necessary data to simulate an on-line GCM run. The major ground hydrology parameterizations are incorporated in steps 3A, 7 and 14. Steps 7 & 14 are similar to those in COMP35 and discussed in Section III, while step 3A was added to parameterize different soil characteristics.

FLOW CHART

OFFLINE

MODEL

Step 1

Design of Experiment

\- - - - - - - -

Step 1A 0LM00350

Set Model Logical Parameters 0LM00700

Model Type	Experiment Type
UCLA	GCM
UCLAVW	ASSIM
UCNI	TNPT
UCNJJA	LOG8
UCN II	VALBFG
	VRP4
	GDH

Cell Type

- WETCEL
- AVCELL
- DRYCEL

\- - - - - - - -

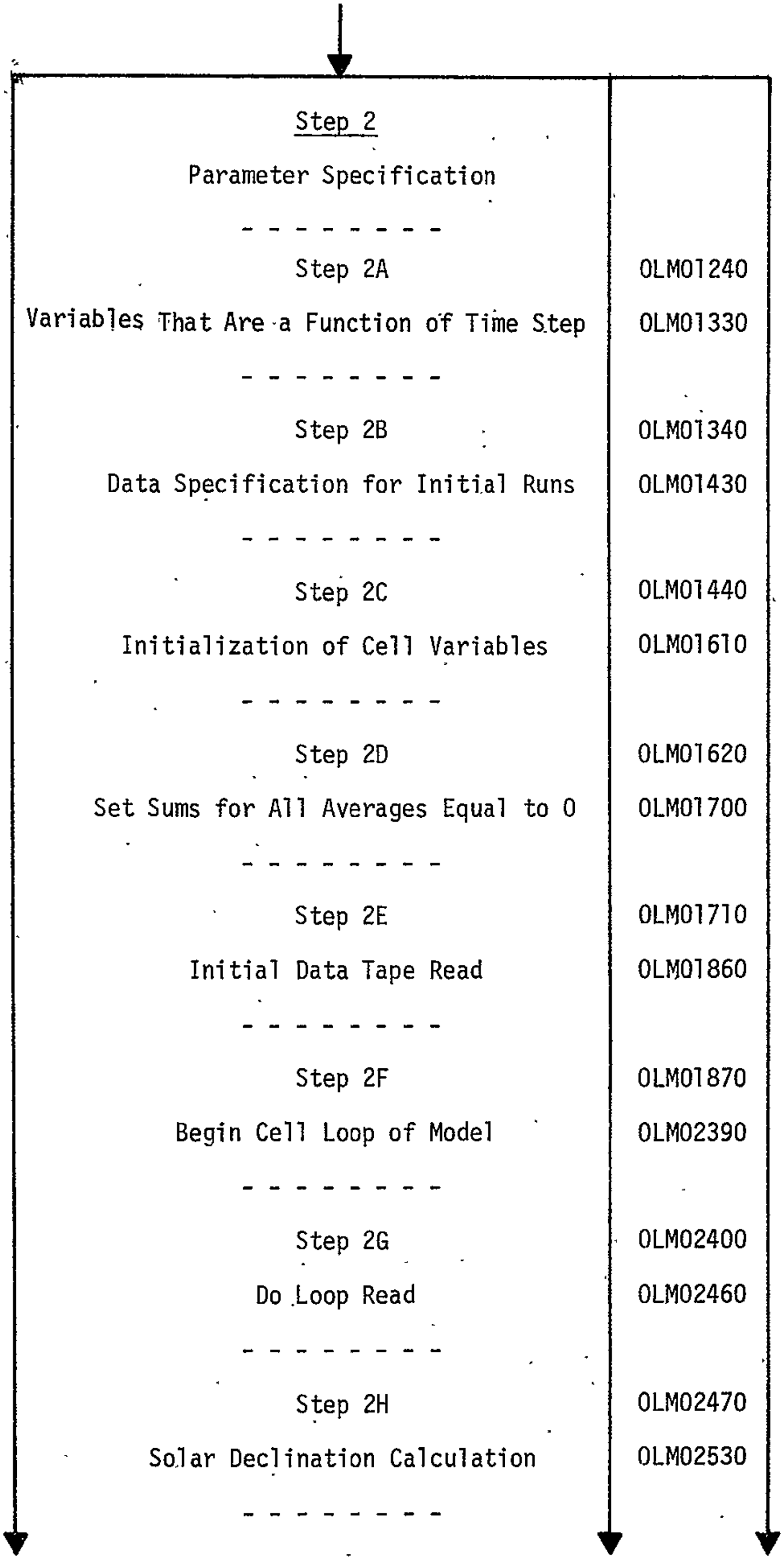
Step 1B 0LM00710

Program Constants 0LM00920

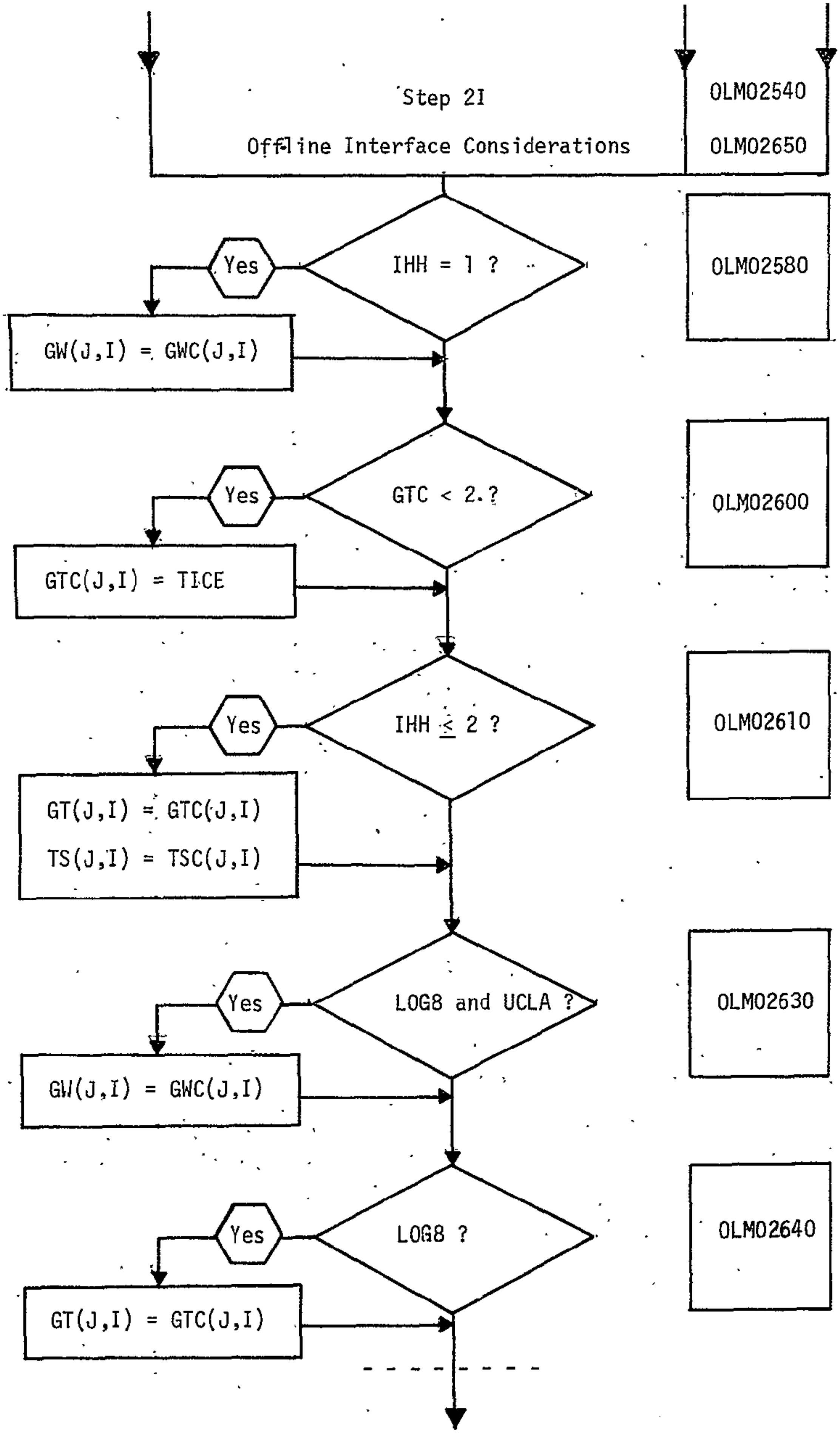
\- - - - - - - -

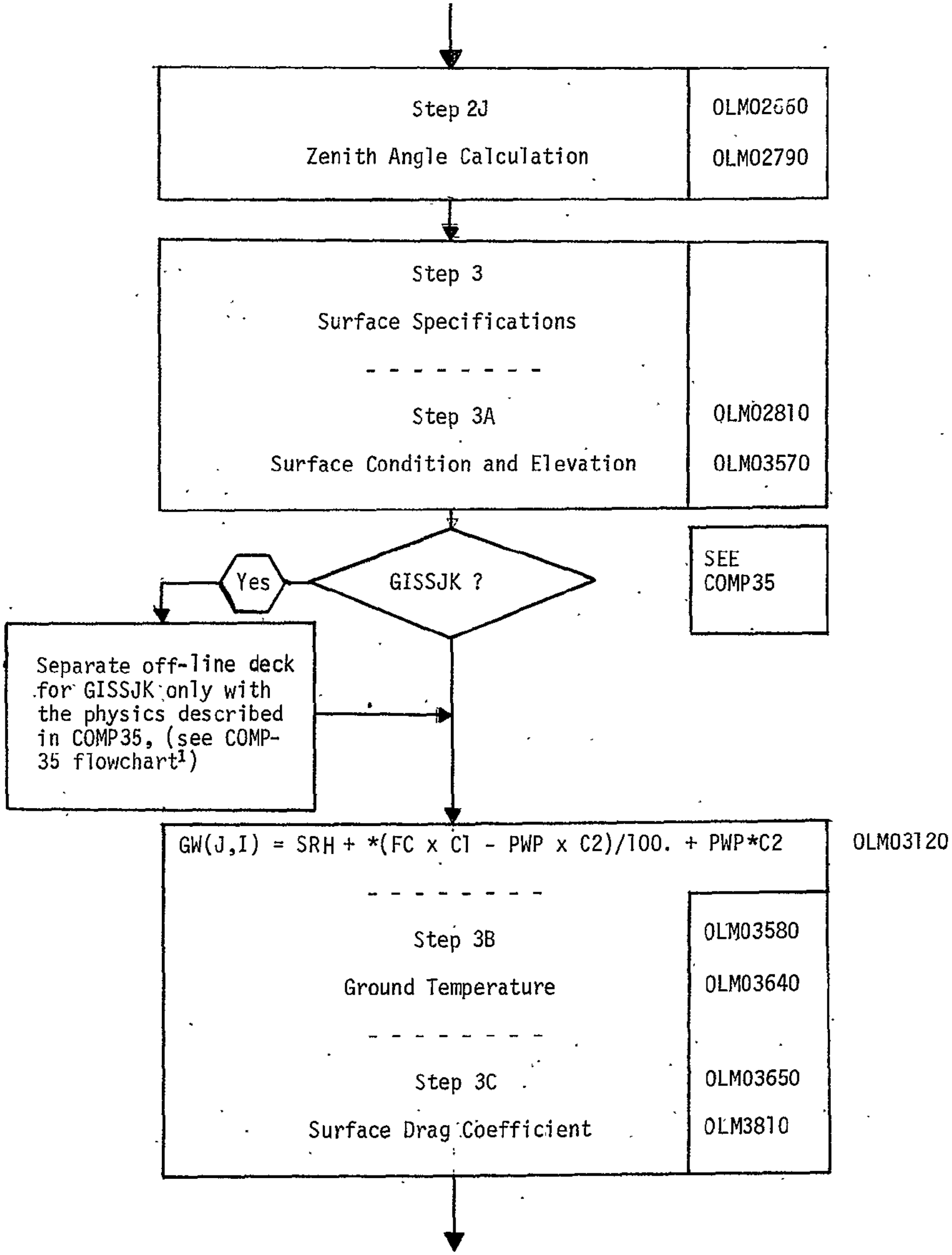
Step 1C 0LM00930

Do Loop Parameters for Specific Cell Locations 0LM01220

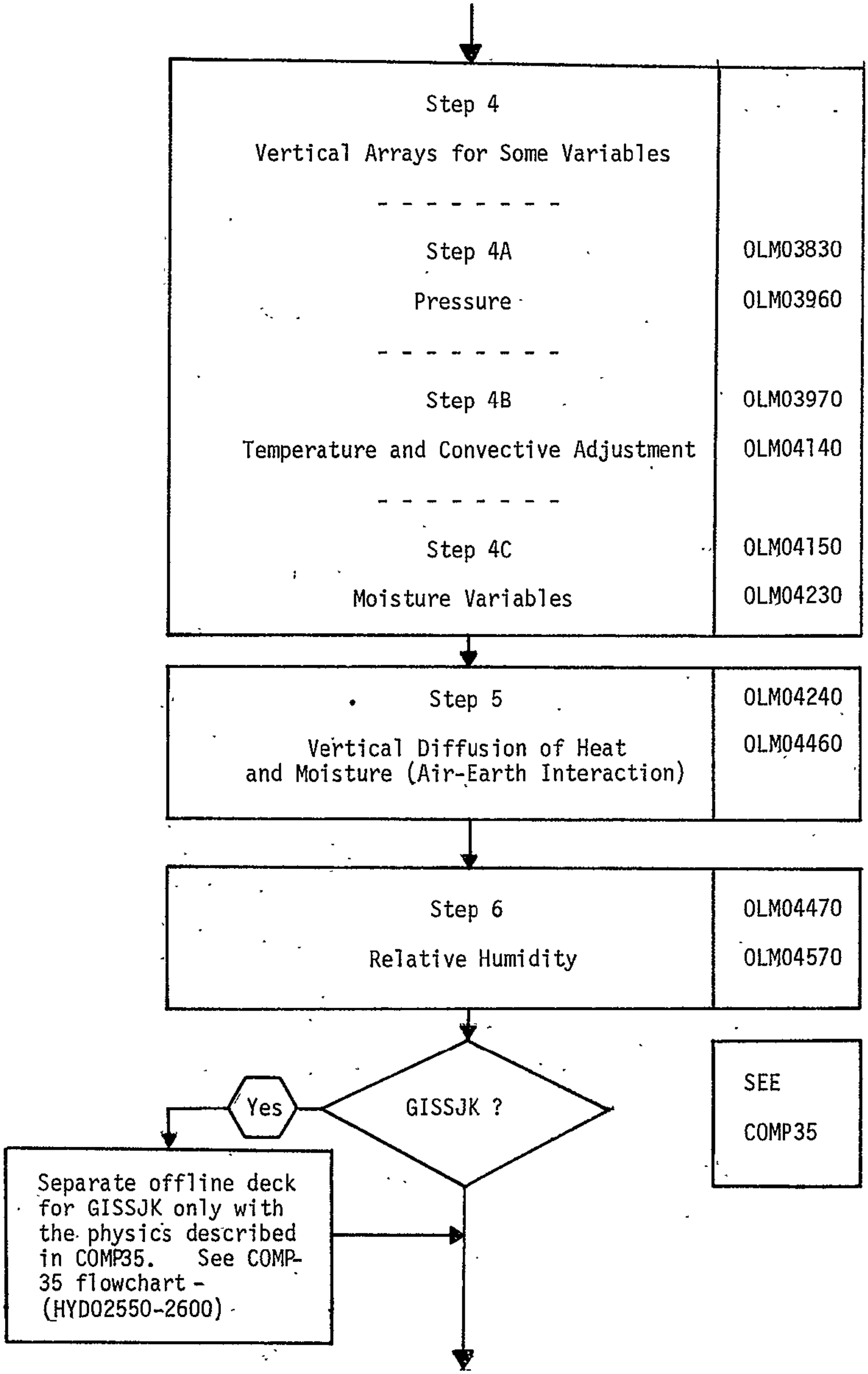


Step 2 Parameter Specification	
Step 2A Variables That Are a Function of Time Step	OLM01240 OLM01330
Step 2B Data Specification for Initial Runs	OLM01340 OLM01430
Step 2C Initialization of Cell Variables	OLM01440 OLM01610
Step 2D Set Sums for All Averages Equal to 0	OLM01620 OLM01700
Step 2E Initial Data Tape Read	OLM01710 OLM01860
Step 2F Begin Cell Loop of Model	OLM01870 OLM02390
Step 2G Do Loop Read	OLM02400 OLM02460
Step 2H Solar Declination Calculation	OLM02470 OLM02530


Step 21
Offline Interface Considerations
OLM02540
OLM02650
IHH = 1 ?
Yes
GW(J,I) = GWC(J,I)
OLM02580
GTC < 2.?
Yes
GTC(J,I) = TICE
OLM02600
IHH ≤ 2 ?
Yes
GT(J,I) = GTC(J,I)
TS(J,I) = TSC(J,I)
OLM02610
LOG8 and UCLA ?
Yes
GW(J,I) = GWC(J,I)
OLM02630
LOG8 ?
Yes
GT(J,I) = GTC(J,I)
OLM02640



HYD01240 - 1260
HYD03000 - 3740


Step 4
Vertical Arrays for Some Variables
Step 4A
Pressure
0LM03830
0LM03960
Step 4B
Temperature and Convective Adjustment
0LM03970
0LM04140
Step 4C
Moisture Variables
0LM04150
0LM04230
Step 5
Vertical Diffusion of Heat and Moisture (Air-Earth Interaction)
0LM04240
0LM04460
Step 6
Relative Humidity
0LM04470
0LM04570
GISSJK ?
Yes
SEE COMP35
Separate offline deck for GISSJK only with the physics described in COMP35. See COMP-35 flowchart (HYD02550-2600)

Step 7	
Determination of Surface Temperature	
- - - - - - - - -	
Step 7A	OLM04580
Initialization	OLM04660
TLE (NLAYP1) = TS(J,I)	OLM04620
- - - - - - - - -	
Step 7B	OLM04670
Relative Humidity Scale	OLM04700
- - - - - - - - -	
Step 7C	OLM04710
Bulk Aerodynamic Coeff	OLM04760
- - - - - - - - -	
Step 7D	OLM04770
Surface Diffusion Coefficient	OLM04810
- - - - - - - - -	
Step 7E	OLM04820
Eddy Diffusivity (see TK and NCAR)	OLM05080

T&K:

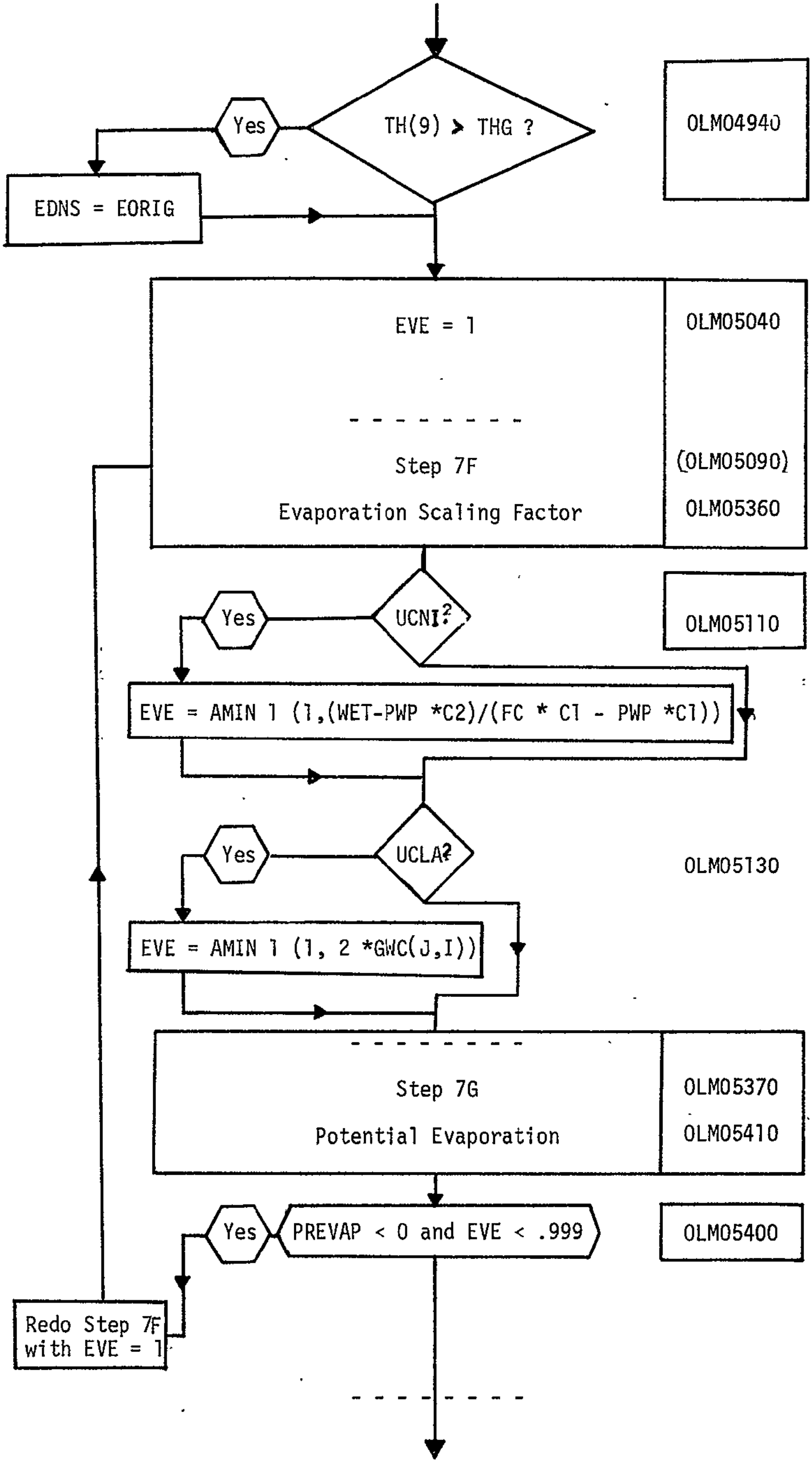
EDNS = AMIN1(100., ED x EXP (.32 *DTS/WMAGNxx2)

EORIG = EDNS

ZLN = ZLNCO x TLE (NLAYPI) x SP/PS
New EDNS formulation
NCAR w/no countergradient (Used in GCM Data Tape Creation)

NCAR:

EDNS = 10. + 100. *(1-EXP (1200.*((TH(NLAY) - THG)/ZLN))
Can't use above calculation for TH(9) >THG. Best that can be done offline with data from levels 7, 8 & 9.


TH(9) > THG ?
Yes
EDNS = EORIG
OLM04940
EVE = 1
OLM05040
Step 7F
Evaporation Scaling Factor
(OLM05090)
OLM05360
UCNI?
Yes
OLM05110
EVE = AMIN 1 (1,(WET-PWP *C2)/(FC * C1 - PWP *C1))
UCLA?
Yes
OLM05130
EVE = AMIN 1 (1, 2 *GWC(J,I))
Step 7G
Potential Evaporation
OLM05370
OLM05410
Yes
PREVAP < 0 and EVE < .999
OLM05400
Redo Step 7F
with EVE = 1

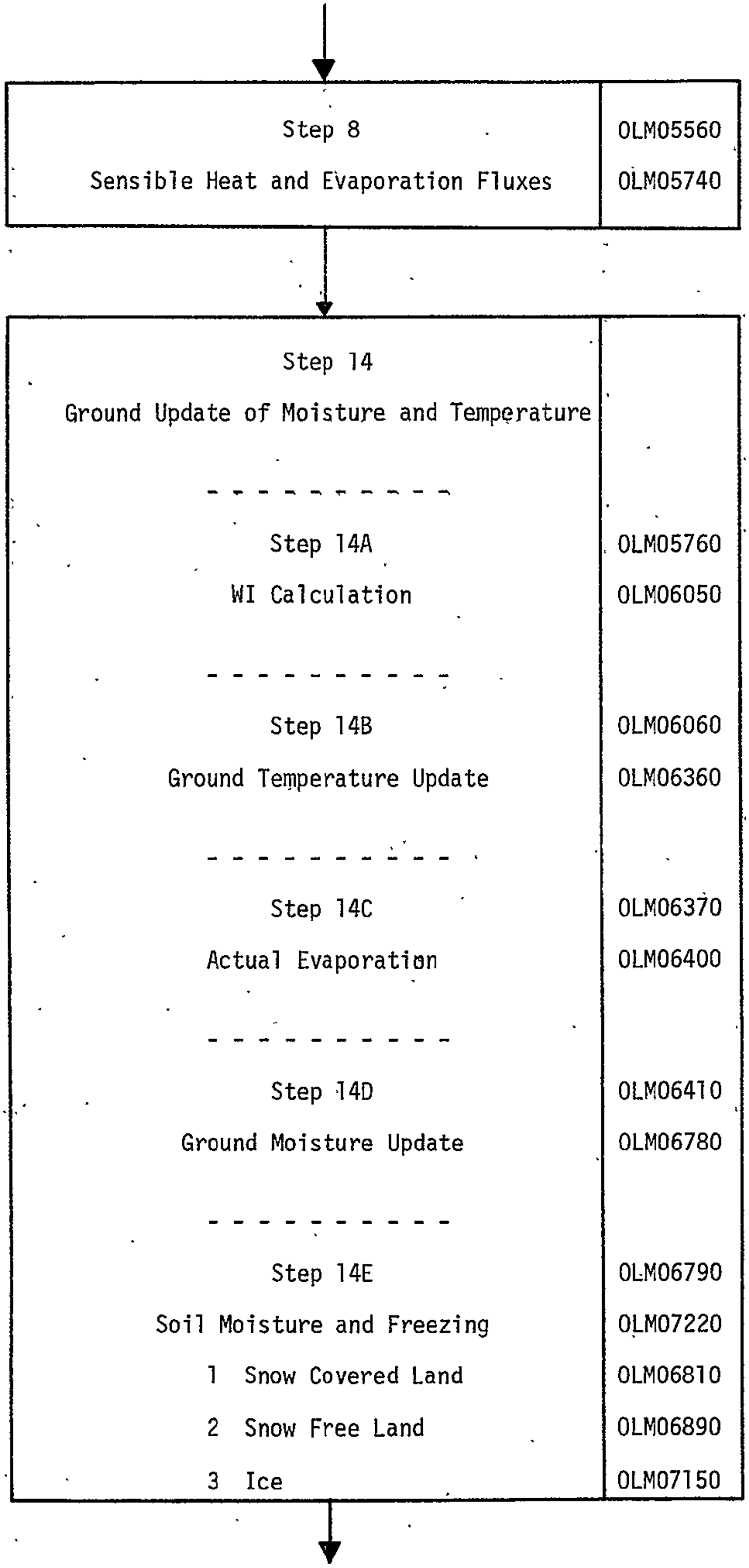
Step 7H

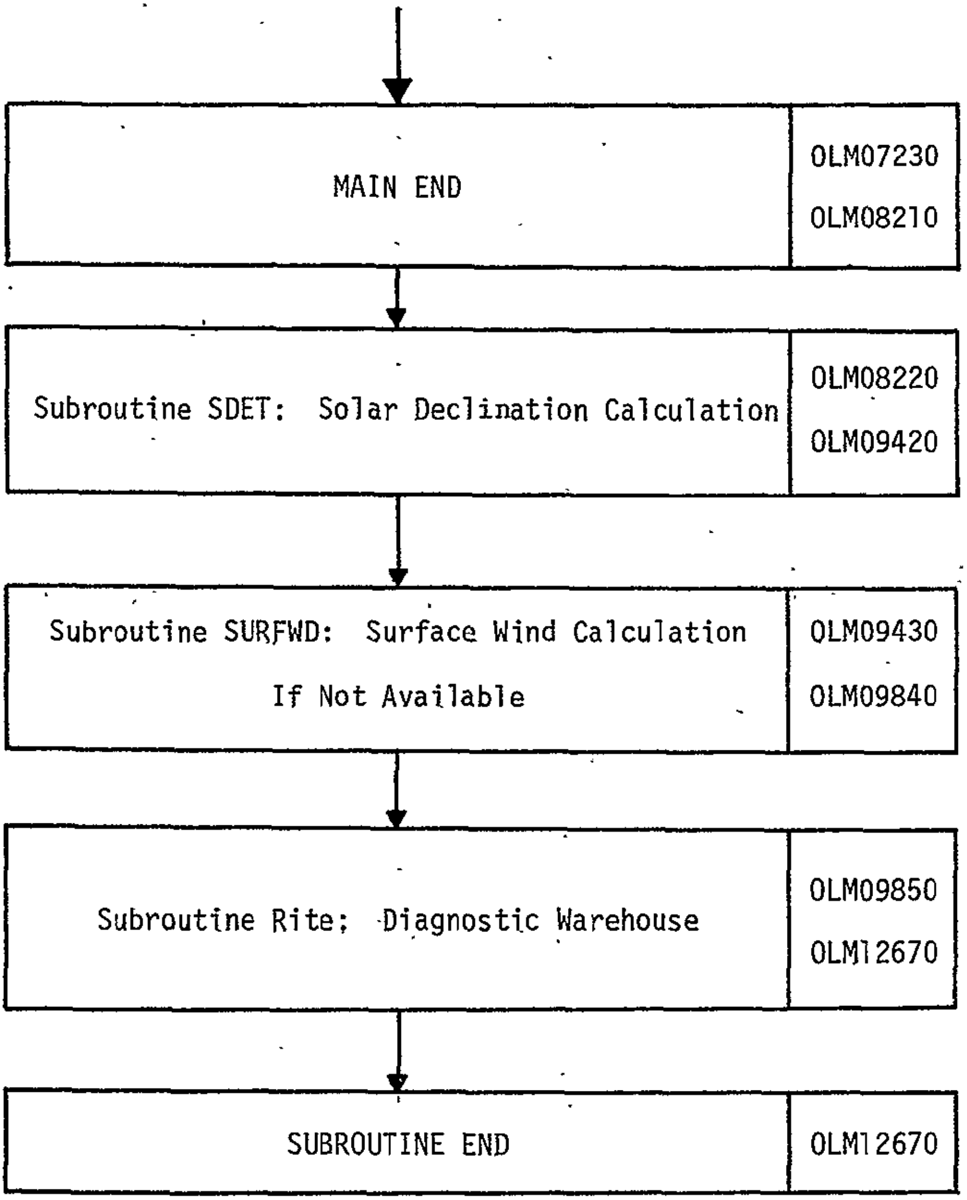
Potential Evaporation Using LOG8 Input

OLM05420
OLM05550

Note:
Potential Evaporation Calculation Differences

Offline (Step 7G)	UCLA (GCM Data Run - Step 7H)
Wet from UCNI or UCLA	Wet from Data Tape
Eve from UCNI or UCLA	Eve from UCLA
Step 7F adjust SHLE (10)	Step 7F adjust SHLE (10)
where SHLE = f(EDV, ...)	where SHLE = f(EDV,....)
SHG = QSAT (TG,PS)	SHG = QSAT(TG,PS)
for LOG8 False:	
TG from previous calculation	
for LOG8 true:	
TG from GCM tape	TG always from GCM data tape


Step 8
Sensible Heat and Evaporation Fluxes
OLM05560
OLM05740
Step 14
Ground Update of Moisture and Temperature
Step 14A
WI Calculation
OLM05760
OLM06050
Step 14B
Ground Temperature Update
OLM06060
OLM06360
Step 14C
Actual Evaporation
OLM06370
OLM06400
Step 14D
Ground Moisture Update
OLM06410
OLM06780
Step 14E
Soil Moisture and Freezing
OLM06790
OLM07220
1 Snow Covered Land
OLM06810
2 Snow Free Land
OLM06890
3 Ice
OLM07150


MAIN END
OLM07230
OLM08210
Subroutine SDET: Solar Declination Calculation
OLM08220
OLM09420
Subroutine SURFWD: Surface Wind Calculation If Not Available
OLM09430
OLM09840
Subroutine Rite; Diagnostic Warehouse
OLM09850
OLM12670
SUBROUTINE END
OLM12670

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Appendix A

Symbols and Notations

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
ADINF	antecedent soil moisture indicator		HYD 06560
ADDW	water which may enter the soil to be evaporated	cm/hh	HYD 06610 06620
ASM	available soil moisture .15 - composite soil .066 - sandy soil (desert)	% sat	HYD 03040 03090
BBFACT	effective infiltration rate	cm/ΔT=30 min	HYD 06570
BETA2	scaling factor for bare soil evapotranspiration rate (β)		HYD 03310 03660 03730
BETA2P	scaling factor for plant influence on transpiration		HYD 03640
BTA	= BETA2 + BETA2P ($0 \leq$ BTA ≤ 1)		HYD 03670 03680 03720
BTA2	argument of BETA2 coefficient		HYD 03540
BT2P	argument of BETA2P coefficient for transpiration		HYD 03560 03620
CD	surface drag coefficient		HYD 02140 02150 02160
CZH	$\left(\frac{\lambda c}{\omega}\right)^{1/2}$, bulk heat capacity where λ = thermal conductivity c = specific heat ω = diurnal angular frequency	cal/cm^2-deg cal/cm-sec-deg cal/cm^3-deg 1/sec	HYD 05040 05050 05060 05090 05120 05150 05160 05270

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
DENOM	storage variable used in ground temp. eq.	ly/day-cm^2-day	HYD05540
DRAW	$C_D W_S$ surface wind drag parameter	m/sec	HYD02690 02700 04000 04010
DRNG	water which is unavailable for ET due to field capacity being exceeded loss of water through percolation when WETR >.5		HYD06090 06670
DRRN	see DRAW		HYD03490 03500
DSHS	$\Delta q_G = q^*_g - q_g$ saturation specific humidity at the ground minus specific humidity at the ground		HYD03990
DTRBET	$\partial/\partial T_g$ of (evapotranspiration)		HYD03700 03710 05420 05430 05440 05460
DTSI	difference between ground temperature	°C	HYD03480
DTS	$T_G - T_S = \Delta T_g$ = difference between ground and surface air temperature	°C	HYD02680
DU	temporary storage variable		HYD02810 02860 02890
DV	temporary storage variable		HYD02830 02870 02910
ECAR	= E6DT/(1-ROCK) (Note: EVE in E6DT is equal to (1-ROCK)·EVE so ROCK affect cancels out in evaporation calculation)		HYD06630

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
EGDT	evaporation rate from soil at grid pt	$\frac{g(H_2O)}{cm^2}$ /ΔT=30	HYD05950
ETFLX	evaporation flux for diagnostic purposes		HYD05900 05910 05920
EVACO	=EVE·DRAW		HYD03780 03790
EVAL	= 600 , latent heat coeff land 680 " " - snow, frost = 680 + 80WI, FOR MIXWI CONDITION	$\frac{cal}{g(H_2O)}$	HYD05030 05080 00110 00140 00180 00260
EVE	soil surface wetness coeff		HYD02980 03740 03770 03830
EXPTI	argument of evapotranspiration coeff		HYD03530 03550
EXDTR	storage variable		HYD03690
EXPTP	does not permit BT2P to become too large		HYD03630
EXPTS	keeps BTA2 from becoming too large		HYD03650
FILTF	infiltration rate derived from viscosity relation -f(t) only not soil type or antecedent precipitation	cm/ΔT=30 min	HYD03220 03270
FREEZ	amt of water that freezes or melts (%)		HYD06050 06770 06810
FLDRK			HYD06080
FXTRN	not used		HYD03020 03450

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
GAMCN	$r_s \frac{q}{C_p} (\Delta Z)_{bdy} \frac{1 + \frac{L}{G_p K} \frac{q^*_s}{T_s}}{1 + 5418 \frac{L}{C_p} \frac{q^*_s}{T^2_s}}$		HYD03360
GAMCN	see GAMC		HYD03360
GAMSN	same as GAMS		HYD03410
GDH	logical variable, if true CD=.5CD		INPUT
GNFLX	variable for diag. purposes		HYD05940
GSW	how often (in hrs) print out will occur		
GT	ground temperature	°K	HYD05570 06920
GW	ground wetness (% sat.) =FLOAT(ISNR) +.5 WETR		HYD01210 01230 01260 01270 01280 01290 01300 01330 01350 01420 01430 01440 01450 01460 06960
IGVET	=13 =21 - dry land, GW = 0 =23 =24 - snow thickness - function of albedo		INPUT
ISNR	integer storage		HYD06200 06950

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
ITC	print variable - allows a portion of J & I cells to be printed when GSW occurs		
IALB	storage for I		HYD01090
PLANT	a variable which decreases transpiration from plants when the solar zenith is greater than 75°		HYD03570 03080 03600
POTALP	precipitation	cm/time step	HYD07080
PREVAP	potential evapotranspiration	$\frac{\text{mm-g}(H_2O)}{\text{cm}^3\text{-hr}}$	HYD03210 03510
QSAT	saturation specific humidity function	g/g	HYD00890
RADTRM	net radiation term	ly/day	HYD05560 05880
RAIN		cm/hh	HYD06030 06190 06540
RHS	surface relative humidity		HYD02530 02550 02580 02650 02660
RNIT	=RADTRM(6.9×10^{-4}) for diagnostic		HYD05890
ROCK	areal fraction devoid of soil, impervious soil	%	HYD03030
$ROK(J_1I)$	same as ROCK		INPUT
RSURF	decimal value for albedo		HYD01520 01550 01560 01570
RSURFF	variable that determines soil type from albedo array		HYD03060 3070

FORTRAM SYMBOL	MEANING	UNITS	PROGRAM LOCATION
RUNOFF	water that does not infiltrate soil col.	$\frac{\text{cm water}}{\Delta T=30\text{ min}}$	HYD06060 06440 06580 06590 06660
RUNOVV	water that runs off impervious area and is unavailable for evapotranspiration		HYD06100 06650
RICH	Richardson No.		HYD02930
SATI	saturation specific humidity		HYD03290 03390
SHG	saturation specific humidity at the ground	g/g	HYD03190
SHLE	sat. specific humidity f(DRAW)	g/g	HYD03750
	" f(BETA2)		03880
	" f(EVACO)		03950
SHSATS	sat. specific humidity at the surface air temperature	g/g	HYD03800
SLBEDO	albedo		
	7 = ocean		HYD01500
	14 = land		01490
	35 = desert		01510
	39 =		
	40 = snow	.5 cm	
	50 = snow	1.0 cm	
	70 = snow	2.0 cm	
SMELT	snowmelt	cm/hh	HYD06070 06280 06290
SNFAL	snow fall	cm/hh	HYD06040 06180
SNFLX	sensible heat flux		HYD05860 05870 05930
SNOTEM	storage location		HYD01540

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
SNR	thickness of snow or change	cm or cm/hh	HYD06000 06210 06220 06240 06310 06940 06510
SNR1	snow thickness	cm or cm/hh	HYD06230
TERM1	short wave radiation	ly day^{-1}	HYD05470
TERM2	sensible heat	cal cm^{-2} day^{-1}	HYD05480 05490
TERM3	evaporation flux	"	05500 05510
TERM4	sea ice heat flux from ocean	"	05520
TERM5	long wave radiation	"	05530
TGM	=WAT, used for printout of WAT		HYD02640 07040
TGN	used for printout of WAT		HYD07030 07050
TGR	ground temperature	°K	HYD06020 06160 06300 06720 06820 06900
THG	potential temp of air		
TOTALP	model predicted precipitation	m/hh	HYD06170
TPMN	print variable		
UGTC	storage variable		HYD03240

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
USM	unavailable soil moisture (%) .025 sand soil (desert) .1 composite soil Ref. Salter & Williams '64, Table I, p. 312		HYD03050 03100
VALBFG	model control variable		
VIGT	viscosity correction factor		HYD03250 03260
VGTC	centigrade temp. of ground	deg	HYD03230
VPM	composite soil moisture		HYD03180
VP1	% of available soil moisture (temp.stor)		HYD03150 03160 03170
VP2	% of unavailable soil moisture ( )		
VSM	total soil moisture	% sat	HYD03140
WAT	soil moisture available for evaporation scaled up	% sat	HYD02590 02600 02610 02620 02630
WET	ground wetness	% sat	HYD01580 01670 04900 04910 05340
WETIT	water available same as WAT	% sat	HYD04880 04890
WETR	amount of water	% sat	HYD05990 06430 06450 06640 06680 06700 06710 06910
WGM	max water holding capacity or sul moist cont at saturation	g/foot soil	HYD03000 03110 03130
	= 2 sandy soil = 2·16.6 composite soil	g/foot soil	

FORTRAN SYMBOL	MEANING	UNITS	PROGRAM LOCATION
WI	% of ice in mixed ice and water	%WET	HYD05190 05210 05220 05230 05240 05250 05350 05730 05740
WIR	"	"	HYD06010 06780 06790 06800
WMAG	W_s wind speed at ground	m/sec	HYD02100 02120 02130
WMAGN	"	"	HYD02710 02720
WTER	% of saturation for ground in desert regions	% sat	HYD01240 01250
WTSTO	stores WET	% sat	HYD04870
XRS	used for point out of RHS		HYD03200 07070

Appendix B

Code Listing - GHM & Off-Line Models (OLM)

ON-LINE LISTING (GHM)

```
      SUBROUTINE COMP35(J,JCENT,JUP,KDN,KCENT,KUP)
C
C     THIS SUBROUTINE WAS ADDED TO PREVENT COMP3 FROM EXCEEDING THE
C     COMPILER LIMIT FOR OPTIMIZATION (OPT=2). IT COMPRISES THE INNER
C     LOOP OF COMP3.
C
C**** THIS IS COMMON BLOCK CMS1 CREATED MAY 8 74
      LOGICAL*4 FLAGS,SPINUP,GDH
      REAL*4 KAPA,LAT
      DIMENSION LAT(46),DXU(46),DXP(46),DYU(46),DYP(46),SINL(46),
     1 COSL(46),DXYP(46),F(46),C(300),C1(300),DUMMY(72)
      DIMENSION PHIS(46,72),MAP(46,2),F2(46,72)
      DIMENSION Q(72,9,11,4)
      DIMENSION QT(72,9,11,4)
      DIMENSION U(72,9,11),V(72,9,11),T(72,9,11),SH(72,9,11)
      DIMENSION UT(72,9,11),VT(72,9,11),TT(72,9,11),SHT(72,9,11)
      DIMENSION P(72,11),PT(72,11)
      DIMENSION PU(72,9,2),PV(72,9,2),PVUP(72,9,2),PUOLD(72,9,2)
      DIMENSION CONV(72,9),SD(72,9),PIT(72),SD1(9),CONSP(9)
      DIMENSION NMSAVE(46),ALFSAV(46)
      DIMENSION PHI(72,9,2),PHIOLD(72,9,2),SPA(72,9,2),SPAOLD(72,9,2)
      DIMENSION PU2(72,9,2),PU2OLD(72,9,2)
      DIMENSION PU3(72,9)
      DIMENSION US(72,2),VS(72,2),QS(72,2,2),WINDSQ(72,2)
      DIMENSION UFIL(72,9),VFIL(72,9),TFIL(72,9),SHFIL(72,9),PFIL(72)
      DIMENSION GRUP(46,72,4)
      DIMENSION SHS(46,72),GT(46,72),GW(46,72),TOFCC(46,72),TS(46,72)
      C O M M O N
     *  JSP,JNP,IM,NLAY,PTROP,ISTART,JSPP1,JNPM1,FIM,NLAYM1,NLAYP1,
     *  J1,JM,KM,TAUT,IROT,MROT,TAUTHT,MROTHT,
     *  NR,JAYS(12),INCS(11),JSB,JNB,DLAT,DLON,JTEST,ITEST,
     *  DT,TAU,ITAU,XINT,IDAY,JDAY,TOFDAY,JDATE,JMONTH(2),JYEAR,NSTEP,
     *  NCYCLE,NCOMP3,NHOGAN,TAUP,TAUI,TAUE,TAUC,
     *  PI,GRAV,RGAS,KAPA,PSL,ED,EMU,NFLW,FSF,NRCH,RSDIST,SIND,COSD,
     *  NC3T,MRCC3T,LC3T,PROJAR,TOTAPS,SCX,ISPACE,SOMULT,DUMMY1(5),
     *  IVER,CDH,RHMAX,FCU,SPINUP,MACHIN,
     *  IALTER,NNINE,PTE,PTE2,NIMPTS,SETNIM,MINJ,MAXJ,IRAND,IRTYPE,ISS,
     *  SS,IDIAG,PERIOD,ALPHA(4),BETA,GAMMA(4),TIMEO(4),KTPB,RINFLU,
     *  MODELT,LRAD(16),NMCT,NRAD(16),KTPA,JTAPE,CDX,FLAGS(10),
     *  MINI,MAXI,CLH,DUMMY2(20),TINT,
     *  XLABEL(20),SIG(20),DSIG(20),SIGE(21),DSIGE(19),
     *  J1PS(11),JMPS(11),J1US(11),JMUS(11),J1P,JMP,J1U,JMU,J1PV,JMPV,
     *  INC,J1PY,J1PM1,JMPY,JMPP1,JMPP1X,J1UX,J1UM1,J1UM1X,JMUX,FINC,
     *  INC2,INCH,
     *  LAT,DXU,DXP,DYU,DYP,SINL,COSL,DXYP,F,DUMMY,NTAE,PHIS,MAP,F2,
     *  P,Q,PU,PV,PUOLD,PVUP,CONV,PIT,PHI,PHIOLD,SPA,SPAOLD,PU2,
     *  PU2OLD,PU3,PITSP,SD1,NMSAVE,ALFSAV
      EQUIVALENCE (JSP,C(1))
      EQUIVALENCE (P(1,1),C1(1))
      EQUIVALENCE (P(1,1),PT(1,1))
      EQUIVALENCE (QT(1,1,1,1),G(1,1,1,1))
      EQUIVALENCE (Q(1,1,1,1),U(1,1,1),UT(1,1,1))
      EQUIVALENCE (Q(1,1,1,2),V(1,1,1),VT(1,1,1))
      EQUIVALENCE (Q(1,1,1,3),T(1,1,1),TT(1,1,1))
      EQUIVALENCE (Q(1,1,1,4),SH(1,1,1),SHT(1,1,1))
```

```
      EQUIVALENCE (SC(1,1),CONV(1,1))
      EQUIVALENCE (SC1(1),CONSP(1))
      EQUIVALENCE (QS(1,1,1),US(1,1),PU(1,1,1)),(VS(1,1),QS(1,1,2),
     1 PU(1,3,1))
      EQUIVALENCE (WINDSQ(1,1),PU(1,5,1))
      EQUIVALENCE (UFIL(1,1),U(1,1,1)),(VFIL(1,1),V(1,1,1)),
     1 (TFIL(1,1),T(1,1,1)),(SHFIL(1,1),SH(1,1,1)),(PFIL(1),P(1,1))
      EQUIVALENCE (GRUP(1,1,1),SHS(1,1)),(GRUP(1,1,2),GT(1,1)),
     1 (GRUP(1,1,3),GW(1,1)),(GRUP(1,1,4),TCFCG(1,1))
      EQUIVALENCE (GRUP(1,1,1),PU(1,7,1)),(TS(1,1),U(1,3,6))
C**** ARRAYS FOR SPLIT GRID
      LOGICAL JIPL(46),JIUL(46),JMPL(46),JMUL(46)
      INTEGER INCP(46),INCU(46)
      COMMON/SPLIT/ JIPL,JIUL,JMPL,JMUL,INCP,INCU
C
      LOGICAL LAND,OCEAN,ICE,SNOW,MIXWI,FROST,PREC
      COMMON/RADCON/AS(15),RE(16),PL(15),PLE(16),PLK(15),PLKE(16),TL(15)
     * ,TLE(16),TG,TH(15),SHL(15),SHLE(16),SHC,CLOUD(15),CCSZ,SP,SG,CXL,
     * OCEAN,ICE,SNOW,SHSAT(15),GAM(15),RH(15),SSS(15),SSSF(15),HH(15),
     * HHE(16),HHS(15),CVT(15),CVQ(15),CXDE(15),PREC(15),EXL(15),
     * COE(15)
      COMMON/CMP3CM/TWOFI,DTC3,SDAY,ZENCC,TICE,FM,CTI,CTIC,HICE,
     * GAMFAC,COEF,COEFS,RSOIN,ROT,PI180,SNOWN,SNOWS,COEF1,COEF2,
     * WMAGSP,WMAGNP,M1,M2,M3,NCL,LCL1,LCL2,STEO,CP
      COMMON/GRDHYD/ICVET,ITC,GSW,CON1,CON2,CON3,CON4,CON5,CON6,CON7
      COMMON /ALBCOM/ RSURF,SLBEDO(46,72),VALBFG,JALB,IALB
      COMMON /SDOT48/ SDOT(46,72,8),MNMXTS
      DIMENSION ROK(46,72)
      COMMON/ROKK/ROK
      INTEGER*2 SLEECC
      LOGICAL VALBFG
      LOGICAL*4 GWSWCH
C**** LOGICAL FHAJ
      QSAT(X,Y)=.622*(10.**(9.4051-2353./X))/Y
      GWSWCH = .FALSE.
       GWSWCH = AMOD((TAU-TAUI+GSW)/GSW,1.).LT..001
      IF(J.GE.34)GWSWCH=.FALSE.
      IF(J.LE.16)GWSWCH=.FALSE.
      IF (GWSWCH.AND.(J-1+ITC)/ITC*ITC.EQ.J+ITC-1) WRITE(3,2555)
      IMINC=IM
      DO 809 I=1,IM
C        SET THESE QUANTITIES TO ZERO FOR USE IN PREPARING COMP3 TAPE
C        WITH SPLIT GRID
      T(I,1,M2) = 0.
      T(I,2,M2) = 0.
C        SET THESE QUANTITIES TO ZERO FOR USE IN PREPARING COMP3 TAPE
C        SURFACE FRICTION TERMS
      P(I,M2) = U(I,1,M3)
      P(I,M3) = U(I,2,M3)
      U(I,1,M3) = 0.
809   U(I,2,M3) = 0.
      JALB=J
      DO 810 I=INC,IM,INC
      IALB=I
      HACOS=COSD*COS(ROT+(I-1)*DLON)
```

```
      COSZ=SINL(J)*SINC+COSL(J)*HACOS
C**** SURFACE CONDITION
      OCEAN=TOPOG(J,I).GT.1.
      ICE=TOPOG(J,I).LT.-9.9E5
      LAND=.NOT.(ICE.OR.OCEAN)
C**** FRAJ=.NOT.OCEAN.AND.(IGVET.EQ.13)      *********************
      IF(GW(46,72)-10.)   2554,2554,2553
2553  SNOW = LAND.AND.GW(J,I).GT.1.00
      IF(IGVET.EQ.24) GO TO 2552
      SNOW = LAND.AND.(GW(J,I).GT.1.0.OR.SLBEDO(J,I).GE.40)
       IF(SNOW)GW(J,I) = AMAX1(10.5 , GW(J,I))
      GO TO 2552
 2554 IF(GW(J,I).LT.(-0.1))GW(J,I) = 1.0
      WTER=GW(J,I)*5.00+.2690917958
      WTER=.5*WTER
      IF(LAND) GW(J,I)=.5*(GW(J,I)*.3+.4)
      IF( SLBEDO(J,I).EQ.35       )GW(J,I)=AMIN1(1.,WTER  )
      GW(J,I) = GW(J,I)/2.
      IF(LAND.AND.IGVET.EQ.21)GW(J,I) = 0.0
      IF(OCEAN) GW(J,I) = 0.50
      IF(IGVET.EQ.24) GO TO 25521
      IF(OCEAN) GO TO 2552
      IF  (LAT(J).GE.SNOWN)GW(J,I)=GW(J,I)+INT  ((LAT(J)-SNOWN)/(LAT(JNP)-
     * SNOWN) *3.E4)
      IF(LAT(J).LE.SNOWS) GW(J,I) = GW(J,I) + INT((LAT(J)-SNOWS)/(LAT(1)
     * -SNOWS) *3.E4 )
      GO TO 2552
25521  IF(SLBEDO(J,I).LE.39) GO TO 2552
C**** SNOW THICKNESS IN CMS.=0.5,1.0,2.0 FOR ALBEDO=40,50,,70 PERCENT.
C**** BESIDES HAVING THICKNESS OF 30CMS AT SOUTH POLE AND PERMANT ICE.
C****                WITH MAXM ALBEDO OF 80 PERCENT.
      GW(J,I) = 2.000E03      +0.5
      IF(SLBEDO(J,I).LT.50) GW(J,I) = 0.500E03+ 0.5
      IF(SLBEDO(J,I).LT.70) GW(J,I) = 1.0E03  + 0.5
      IF(ICE)GW(J,I) = 30.0E03+0.5
      IF(J.LE.9.AND.LAND) GW(J,I)=30.0E03+0.5
      SNOW = LAND.AND.GW(J,I).GT.1.01
2552  IF(VALBFG) GO TO 2556
      SLBEDO(J,I) = 14
      IF(OCEAN)SLBEDO(J,I) = 7
      IF(SNOW.OR.ICE) SLBEDO(J,I) = 70
 2556 RSURF = 0.01*SLBEDO(J,I)
      IF(IGVET.NE.24.OR.GW(J,I).LT.1.01) GO TO 25566
      SNOTEM = SQRT((GW(J,I)-0.5)/1000.)
      RSURF = 0.50*SNOTEM
      IF(SNOTEM.LT.1.)RSURF = RSURF+0.01*SLBEDO(J,I)*(1.-SNOTEM)
      RSURF = AMIN1(RSURF,0.80)
25566 WET = AMIN1(1.,(AMOD(GW(J,I),1.)*2))
      LAND=LAND.AND..NOT.SNOW
      MIXWI = GT(J,I) .LE. 1.1 .AND.(LAND.OR.SNOW)
      FROST=LAND.AND.(GT(J,I).LE.TICE).AND..NOT.MIXWI
      IF(.NOT.OCEAN) Z=PHIS(J,I)/GRAV
C**** GROUND TEMPERATURE AND WETNESS
      IF(OCEAN) TG=TOPOG(J,I)
      IF(.NOT.OCEAN) TG=GT(J,I)
```

ORIGINAL PAGE IS
OF POOR QUALITY

```
      IF(MIXWI) TG=TICE                                                 HYD01660
      IF(.NOT.LAND) WET=1.0                                             HYD01670
C                                                                       HYD01680
C                                                                       HYD01690
C**** PRESSURES                                                         HYD01700
      SP = P(I,KCENT)                                                   HYD01710
      COLMR=PM/SP                                                       HYD01720
      DO 30 L=1,NLAY                                                    HYD01730
      PL(L)=SIG(L)*SP+PTROP                                             HYD01740
      PLE(L)=SIGE(L)*SP+PTROP                                           HYD01750
   30 PLK(L)=EXPBYK(PL(L))                                              HYD01760
      PLE(NLAY+1)=SP+PTROP                                              HYD01770
C**** TEMPERATURES AND ADIABATIC ADJUSTMENT                             HYD01780
      DO 35 L=1,NLAY                                                    HYD01790
35    TL(L) = T(I,L,KCENT)                                              HYD01800
      DO 40 N=1,3                                                       HYD01810
      DO 40 L=2,NLAY                                                    HYD01820
      LM1=L-1                                                           HYD01830
      IF(TL(L-1)/PLK(L-1).GE.TL(L)/PLK(L)) GO TO 40                     HYD01840
      THETA=(TL(LM1)*DSIG(LM1)+TL(L)*DSIG(L))/(PLK(LM1)*DSIG(LM1)+      HYD01850
     *  PLK(L)*DSIG(L))                                                 HYD01860
      TL(L-1)=THETA*PLK(L-1)                                            HYD01870
      TL(L)=THETA*PLK(L)                                                HYD01880
   40 TH(L-1)=TL(L-1)/PLK(L-1)                                          HYD01890
      TH(NLAY)=TL(NLAY)/PLK(NLAY)                                       HYD01900
C SAVE CHANGE IN TEMPERATURE CAUSED BY ADIABATIC ADJUSTMENT HEATING     HYD01910
          DO 45 L = 1,NLAY                                              HYD01920
   45     U(I,L,M1) = TL(L)-T(I,L,KCENT)                                HYD01930
C**** MOISTURE VARIABLES                                                HYD01940
      DO 50 L=1,NLAY                                                    HYD01950
      SHL(L) = SH(I,L,KCENT)                                            HYD01960
   50 CLOUD(L)=0.                                                       HYD01970
      CLOUD(NLAY+1)=0.                                                  HYD01980
      CLOUD(NLAY+2)=0.                                                  HYD01990
      CLOUD(NLAY+3)=0.                                                  HYD02000
C**** ELIMINATE NEGATIVE SPECIFIC HUMIDITY                              HYD02010
      DO 202 L=2,NLAY                                                   HYD02020
      LM1=L-1                                                           HYD02030
      IF(SHL(LM1).GE.0.)  GO TO 202                                     HYD02040
      SHL(L)=SHL(L)+SHL(LM1)*DSIG(LM1)/DSIG(L)                          HYD02050
      SHL(LM1)=0.                                                       HYD02060
  202 CONTINUE                                                          HYD02070
      IF(SHL(NLAY).LT.0.)  SHL(NLAY)=0.                                 HYD02080
C**** DRAG COEFFICIENT                                                  HYD02090
      IF (J.GT.JSP.AND.J.LT.JNP) WMAG = .5*SQRT(WINDSQ(I,JCENT) +       HYD02100
     1 WINDSQ(IMINC,JCENT)+WINDSQ(I,JLP)+WINDSQ(IMINC,JLP))             HYD02110
      IF(J.EQ.JSP) WMAG=WMAGSP                                          HYD02120
      IF(J.EQ.JNP) WMAG=WMAGNP                                          HYD02130
      IF(OCEAN) CD=AMIN1((1.+.07*WMAG)*.001,.0025)                      HYD02140
      IF(.NOT.OCEAN) CD=.002+.006*Z/5000.                               HYD02150
      IF(GDH) CD=0.5*CD                                                 HYD02160
C**** VERTICAL DIFFUSION OF HEAT AND MOISTURE                           HYD02170
70    LMIN = 2                                                          HYD02180
C CHANGE THIS FROM 'LMIN = NLAYM1'                                      HYD02190
      DO 75 L = 1,NLAY                                                  HYD02200
```

```
C IF THE VERTICAL DIFFUSION HEATING TERMS TO BE SAVED ON THE COMP3 TAPE
C ARE NOT COMPUTED IN THE CODE THEY WILL DEFAULT TO ZERO
75    U(I,L,M2) = 0.
      DO 80 L=LMIN,NLAY
      LM1=L-1
      DTETA=(TH(LM1)-TH(L))*(PLK(LM1)+PLK(L))*.5
      DZUP=SP*DSIG(LM1)*RGAS*TL(LM1)/(PL(LM1)*GRAV)
      DZDN=SP*DSIG(L)*RGAS*TL(L)/(PL(L)*GRAV)
      EDLE=.2*ED
      TEMP=DTC3*(DSIG(LM1)+DSIG(L))/(DZUP+DZDN)**2
      FLE=-2.*EDLE*DTETA*TEMP
      TL(LM1)=TL(LM1)+FLE/DSIG(LM1)
      TL(L)=TL(L)-FLE/DSIG(L)
         U(I,LM1,M2) = U(I,LM1,M2)+FLE/DSIG(LM1)
C SAVE VERTICAL DIFFUSION HEATING TERMS
         U(I,L,M2) = -FLE/DSIG(L)
      TH(LM1)=TL(LM1)/PLK(LM1)
      TH(L)=TL(L)/PLK(L)
      DSH=SHL(LM1)-SHL(L)
      ELE=-2.*EDLE*DSH*TEMP
      SHL(LM1)=SHL(LM1)+ELE/DSIG(LM1)
   80 SHL(L)=SHL(L)-ELE/DSIG(L)
C**** SATURATION SPECIFIC HUMIDITY
      DO 100 L=1,NLAY
      SHSAT(L)=QSAT(TL(L),PL(L))
      GAM(L)=GAMFAC*SHSAT(L)/TL(L)**2
      RH(L)=SHL(L)/SHSAT(L)
100   CONTINUE
C**** DETERMINATION OF SURFACE TEMPERATURE
      PS=PLE(NLAY+1)
      PSK=EXPBYK(PS)
      TLE(NLAYP1)=TS(J,I)
      RHS=0.
      THG = TS(J,I)/PSK
      IF(WET+RH(NLAY).NE.0.) RHS=2.*WET*RH(NLAY)/(WET+RH(NLAY))
C     RH SCALE
      IF(.NOT.LAND)GO TO 101
         RHS=0.
      WAT=2.*(1.666666666*2.*WET-.666666666)
      IF(SLBEDO(J,I).EQ.35     )WAT=.2*(2.*WET-.2690917958)
      IF(WAT.GT.1.)WAT=1.
      IF(WAT.LT.0.)WAT=0.
      WAT=WAT*(1.-FOK(J,I))
      TGM=WAT
      IF(WAT+RH(NLAY).GT.0)RHS=WAT*RH(NLAY)/(WAT+RH(NLAY))
      RHS=2.*RHS
  101 CONTINUE
      DTS=TG-TLE(NLAYP1)
      IF(DTS.GE.0.) DRAW=CD*(WMAG+SQRT(DTS))
      IF (DTS.LT.0.) DRAW=CD*WMAG*(WMAG*WMAG)/((WMAG*WMAG)-7.*DTS)
      WMAGN=1.
      IF(DTS.LT.0.) WMAGN=.2*(WMAG+.01)
      ZLN=ZLNCD*TLE(NLAYP1)*SP/PS
      IF (TH(NLAY).GT.THG) GO TO 110
      EDNS = 10.+100.*(1.-EXP(1200.*((TH(NLAY)-THG)/ZLN)))
```

```
      GO TO 112                                                         HYD02760
C     COMPUTATION OF DIFFUSION COEFFICIENT BETWEEN SURFACE AND LAYER    HYD02770
C 'NLAY' WITH NCAR FORMULATION BUT NO COUNTERGRADIENT                   HYD02780
110   IF (J.EQ.JSP) GO TO 113                                           HYD02790
      IF (J.EQ.JNP) GO TO 114                                           HYD02800
      DU = .25*(U(IMINC,NLAY,KUP)-US(IMINC,JUP)+U(I,NLAY,KUP)-US(I,JUP)+HYD02810
     1 U(IMINC,NLAY,KCENT)-US(IMINC,JCENT)+U(I,NLAY,KCENT)-US(I,JCENT)) HYD02820
      DV = .25*(V(IMINC,NLAY,KUP)-VS(IMINC,JUP)+V(I,NLAY,KUP)-VS(I,JUP)+HYD02830
     1 V(IMINC,NLAY,KCENT)-VS(IMINC,JCENT)+V(I,NLAY,KCENT)-VS(I,JCENT)) HYD02840
      GO TO 118                                                         HYD02850
113   DU = .5*(U(IMINC,NLAY,KUP)-US(IMINC,JUP)+U(I,NLAY,KUP)-US(I,JUP)) HYD02860
      DV = .5*(V(IMINC,NLAY,KUP)-VS(IMINC,JUP)+V(I,NLAY,KUP)-VS(I,JUP)) HYD02870
      GO TO 118                                                         HYD02880
114   DU = .5*(U(IMINC,NLAY,KCENT)-US(IMINC,JCENT)+U(I,NL AY,KCENT)-    HYD02890
     1 US(I,JCENT))                                                     HYD02900
      DV = .5*(V(IMINC,NLAY,KCENT)-VS(IMINC,JCENT)+V(I,NLAY,KCENT)-     HYD02910
     1 VS(I,JCENT))                                                     HYD02920
118   RICH = GRAV*((TH(NLAY)-THG)/ZLN)/(TG*((DU/ZLN)**2+(DV/ZLN)**2+    HYD02930
     1 1.E-12))                                                         HYD02940
      EDNS = 10./(1.+40.*RICH)+2.                                       HYD02950
112   CONTINUE                                                          HYD02960
      EDV=EDNS/ZLN                                                      HYD02970
      EVE=AMIN1(1.,2.*WET)                                              HYD02980
C***  ********************* NEW BETA FOR GR. EVAPORATION ********        HYD02990
      WGM=2.*16.66666                                                   HYD03000
      IF(SLBEDO(J,I) .LT.10) GO TO 102                                  HYD03010
      EXTRN=1                                                           HYD03020
      ROCK=ROK(J,I)                                                     HYD03030
      ASM=.15                                                           HYD03040
      USM=.10                                                           HYD03050
      RSURFF=(SLBEDO(J,I)*.01-.35)                                      HYD03060
      RSURFF=ABS(RSURFF)                                                HYD03070
      IF(ABS(RSURFF).GT..01) GO TO 6415                                 HYD03080
      ASM=0.065944                                                      HYD03090
      USM=0.024278                                                      HYD03100
      WGM=2.                                                            HYD03110
 6415 CONTINUE                                                          HYD03120
      WGM=WGM*2.                                                        HYD03130
      VSM=2*WET*(ASM+USM)                                               HYD03140
      VP1=AMAX1(0.,(2.*WET*(ASM+USM)-USM)/ASM)                          HYD03150
      VP2=AMIN1(1.,2.*WET*(ASM+USM)/USM)                                HYD03160
      VP2=AMAX1(0.,VP2)                                                 HYD03170
      VPM=.1*VP2+.2*VP1                                                 HYD03180
      SHG=QSAT(TG,PS)                                                   HYD03190
      XRS=0.                                                            HYD03200
      PREVAP=0.                                                         HYD03210
      FILTF=1                                                           HYD03220
      VGTC=GT(J,I)-TICE                                                 HYD03230
      UGTC=1.7625*EXP(-.036*VGTC)+.44562                                HYD03240
      VIGT=1./UGTC                                                      HYD03250
      IF(VGTC.LT.0) VIGT= 1.0E-21                                       HYD03260
      FILTF=FILTF*VIGT                                                  HYD03270
      SHLE(NLAYP1)=(DRAW*SHG+EDV*SHL(NLAY))/(DRAW+EDV)                  HYD03280
      SATI=QSAT(TLE(NLAYP1),PS)                                         HYD03290
  102 CONTINUE                                                          HYD03300
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      BETA2=1                                                           HYD03310
      IF(LAND.AND..NOT.SNOW)GO TO 1234                                  HYD03320
      GO TO 1235                                                        HYD03330
 1234 CONTINUE                                                          HYD03340
      TEMP=SATI/TLE(NLAYP1)                                             HYD03350
      GAMCN=ZLN*RHS*9.8*(1.-(1.+CLH*TEMP/KAPA)/(1.+GAMFAC*TEMP/         HYD03360
     1TLE(NLAYP1)))*KAPA/RGAS                                           HYD03370
      TNEH=(DRAW*TG+EDV*(TH(NLAY)*PSK-GAMCN))/(DRAW+EDV)                HYD03380
      SATI=QSAT(TNEH,PS)                                                HYD03390
      IF(SHLE(NLAYP1).LE.SATI) GO TO 6120                               HYD03400
      GAMSN=GAMFAC*SATI/TNEH**2                                         HYD03410
      TEMP=(SHLE(NLAYP1)-SATI)/(1.+GAMSN)                               HYD03420
      TNEH=TNEH+TEMP*CLH                                                HYD03430
      SHLE(NLAYP1)=SHLE(NLAYP1)-TEMP                                    HYD03440
      FXTRN=1./BETA2                                                    HYD03450
 6120 CONTINUE                                                          HYD03460
      RHOS=PS/(RGAS*TNEH)                                               HYD03470
      DTSI=.5*(DTS+TG-TNEH)                                             HYD03480
      IF(DTSI.GE.0.) DRRN=CD*(WMAG+SQRT(DTSI))                          HYD03490
      IF(DTSI .LT.0.)DRRN =CD*WMAG*(WMAG*WMAG)/((WMAG*WMAG)-7.*DTSI)    HYD03500
      PREVAP=DRRN*RHOS*100.*(QSAT(TG,PS)-SHLE(NLAYP1))*3600.            HYD03510
      IF(PREVAP.LE.0.) GO TO 1235                                       HYD03520
      EXPTI=AMIN1(170.,16.75*VSM)                                       HYD03530
      ETA2=.01*VSM*EXP(EXPTI)/PREVAP                                    HYD03540
      EXPTI=AMIN1(170.,16.75*VPM)                                       HYD03550
      BT2P=.10*VPM*EXP(EXPTI)/PREVAP                                    HYD03560
      PLANT=AMIN1( 1.,COSZ/.2588)                                       HYD03570
      IF(COSZ.LT.0) PLANT=0.                                            HYD03580
      IF(RSURFF.GT..01) GO TO 4000                                      HYD03590
      PLANT=1.                                                          HYD03600
 4000 CONTINUE                                                          HYD03610
      BT2P=PLANT*BT2P                                                   HYD03620
      EXPTP=-AMIN1(170.,BT2P)                                           HYD03630
      BETA2P=1.-EXP(EXPTP)                                              HYD03640
      EXPTS=-AMIN1(170.,BTA2)                                           HYD03650
      BETA2=1.-EXP(EXPTS)                                               HYD03660
      BTA=BETA2+BETA2P                                                  HYD03670
      IF(BTA.GT.1.) ETA=1.                                              HYD03680
      EXTDR=(EXPTS*EXP(EXPTS)+EXPTP*EXP(EXPTP))                         HYD03690
      DTRBET=(1.-ROCK)*EXTDR                                            HYD03700
      IF(BTA.GT..9999)DTRBET=0.                                         HYD03710
      BTA =(1.-ROCK)*ETA                                                HYD03720
      BETA2=BTA                                                         HYD03730
      EVE=BETA2                                                         HYD03740
      SHLE(NLAYP1)=SHL(NLAY)-BETA2*( SHL(NLAY)-SHLE(NLAYP1))*FXTRN      HYD03750
 1235 CONTINUE                                                          HYD03760
      EVE=1.                                                            HYD03770
      EVACO=EVE*DRAW                                                    HYD03780
      EVACO=AMAX1(EVACO,1.E-40)                                         HYD03790
      SHSATS=QSAT(TLE(NLAYP1),PS)                                       HYD03800
      SHG=QSAT(TG,PS)                                                   HYD03810
C     NEW BETA CONTINUED                                                HYD03820
      EVE=BETA2                                                         HYD03830
      TEMP=SHSATS/TLE(NLAYP1)                                           HYD03840
      GAMC=ZLN*RHS*9.8*(1.-(1.+CLH*TEMP/KAPA)/(1.+GAMFAC*TEMP/          HYD03850
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     *  TLE(NLAYP1)))*KAPA/RGAS                                         HYD03860
      TLE(NLAYP1)=(DRAW*TG+EDV*(TH(NLAY)*PSK-GAMC))/(DRAW+EDV)          HYD03870
      SHLE(NLAYP1)=(EVACO*SHG+EDV*SHL(NLAY))/(EVACO+EDV)                HYD03880
      SHSATS=GSAT(TLE(NLAYP1),PS)                                       HYD03890
      IF(SHLE(NLAYP1).LE.SHSATS) GO TO 120                              HYD03900
      GAMS=GAMFAC*SHSATS/TLE(NLAYP1)**2                                 HYD03910
      TEMP=(SHLE(NLAYP1)-SHSATS)/(1.+GAMS)                              HYD03920
      TLE(NLAYP1)=TLE(NLAYP1)+TEMP*CLH                                  HYD03930
C**** IF(FHAJ)TLE(NLAYP1)=TLE(NLAYP1)-.75*TEMP*CLH    ***************   HYD03940
      SHLE(NLAYP1)=SHLE(NLAYP1)-TEMP                                    HYD03950
  120 RHOS=PS/(RGAS*TLE(NLAYP1))                                        HYD03960
C**** SENSIBLE HEAT (LY/DAY) AND EVAPORATION (CM/CM**2/SEC)              HYD03970
      DTS=.5*(DTS+TG-TLE(NLAYP1))                                       HYD03980
      DSHS=SHG-SHLE(NLAYP1)                                             HYD03990
      IF(DTS.GE.0.) DRAW=CD*(WMAG+SQRT(DTS))                            HYD04000
      IF (DTS.LT.0.) DRAW=CD*WMAG*(WMAG*WMAG)/((WMAG*WMAG)-7.*DTS)      HYD04010
      FSURF=COEFS*RHOS*DRAW/SP                                          HYD04020
      TL(NLAY)=TL(NLAY)+FSURF*DTS                                       HYD04030
C****                                                                   HYD04040
      CON1 = TH(NLAY)*PSK-GAMC                                          HYD04050
      CON2 = DRAW*TG                                                    HYD04060
      IF(IGVET.EQ.13) TL(NLAY) = TL(NLAY) + FSURF*DTS*0.5               HYD04070
C SAVE CHANGE IN TEMPERATURE IN LAYER 'NLAY' CAUSED BY SURFACE          HYD04080
C INTERACTION HEATING                                                   HYD04090
         V(I,9,M2) = FSURF*DTS                                          HYD04100
      IF(IGVET.EQ.13)   V(I,9,M2) = V(I,9,M2) + FSURF*DTS*0.5           HYD04110
C SAVE EVAPORATION IN MM H2O                                            HYD04120
         P(I,M1) = FSURF*EVE*DSHS*100.*DSIG(NLAY)*SP/GRAV               HYD04130
C**** IF(FHAJ)P(I,M1)=.25*P(I,M1)     ****************************      HYD04140
      TH(NLAY)=TL(NLAY)/PLK(NLAY)                                       HYD04150
      SHL(NLAY)=SHL(NLAY)+FSURF*EVE*DSHS                                HYD04160
C**** IF(FHAJ)SHL(NLAY)=SHL(NLAY)-.75*FSURF*EVE*DSHS     *************  HYD04170
      IF(SHL(NLAY).LT.0.)  SHL(NLAY)=0.                                 HYD04180
C    SAVE EVAPORATION AND SENSIBLE HEAT FLUX FOR OCEAN(LY/DAY)          HYD04190
      IF ( .NOT. OCEAN) GO TO 122                                       HYD04200
      EVAL =600.                                                        HYD04210
      TEMP=10.*DRAW*RHOS*SDAY                                           HYD04220
       V(I,3,M3)=EVAL*EVE*TEMP*DSHS                                     HYD04230
       V(I,4,M3)=CP*TEMP*DTS                                            HYD04240
C    SAVE PRECIPITABLE WATER VAPOR(G/CM**2)                             HYD04250
  122  PRECWV=0.                                                        HYD04260
       DO 123 L=1,NLAY                                                  HYD04270
  123  PRECWV=PRECWV+SHL(L)*DSIG(L)                                     HYD04280
      V(I,1,M3)=SP*PRECWV*10./GRAV                                      HYD04290
      FSURFQ=.25*FSURF                                                  HYD04300
      DO 140 K=1,2                                                      HYD04310
      IF (J.EQ.JSP) GO TO 135                                           HYD04320
      Q(I,NLAY,KCENT,K) = Q(I,NLAY,KCENT,K)-FSURFQ*QS(I,JCENT,K)        HYD04330
         P(I,M1+K) = P(I,M1+K) + FSURFQ*QS(I,JCENT,K)                   HYD04340
      Q(IMINC,NLAY,KCENT,K) = Q(IMINC,NLAY,KCENT,K) - FSURFQ*           HYD04350
     1 QS(IMINC,JCENT,K)                                                HYD04360
         P(IMINC,M1+K) = P(IMINC,M1+K) + FSURFQ*QS(IMINC,JCENT,K)       HYD04370
  135 CONTINUE                                                          HYD04380
      IF(J.EQ.JNP) GO TO 140                                            HYD04390
      Q(I,NLAY,KUP,K) = Q(I,NLAY,KUP,K)-FSURFQ*QS(I,JUP,K)              HYD04400
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```
          U(I,K,M3) = U(I,K,M3)  + FSURFC*QS(I,JUP,K)
      Q(IMINC,NLAY,KUP,K) = Q(IMINC,NLAY,KUP,K)-FSURFC*QS(IMINC,JUP,K)
          U(IMINC,K,M3) = U(IMINC,K,M3) + FSURFC*QS(IMINC,JUP,K)
  140 CONTINUE
      SDOT(J,I,3)=TOTALP+SDOT(J,I,3)
C**** ELIMINATE NEGATIVE SPECIFIC HUMIDITY
      DO 410 L=2,NLAY
      LM1=L-1
      IF(SHL(LM1).GE.0.) GO TO 410
      SHL(L)=SHL(L)+SHL(LM1)*DSIG(LM1)/DSIG(L)
      SHL(LM1)=0.
  410 CONTINUE
      IF(SHL(NLAY).LT.0.) SHL(NLAY)=0.
      IF(SHLE(NLAYP1).LT.0.) SHLE(NLAYP1)=0.
C**** RADIATION SUBROUTINES
      IF(NFLW.EQ.0)GO TO 420
      IF (.NOT.FLAGS(1)) GO TO 420
      XDAY=FLOAT(JDAY+62)
      XLAT = (J-.5*(JSP+JNP))*DLAT*180./PI
      LATD = XLAT + .5
      CALL SOLAR1 (NLAY,XDAY,XLAT)
      DSAREA = DXYP(J)*RSQIN
      IF (COSZ.GT..01) PROJAR = PROJAR+DSAREA*COSZ
      TDSABS = SG
      DO 412 L = 1,NLAY
412   TDSABS = TDSABS+AS(L)
      TOTABS = TOTABS+TDSABS*DSAREA
      CALL LINKHO (NLAY,NFLW,JDAY,LATD)
C   SAVE SOLAR RADIATION INCIDENT ON TOP OF ATMOSPHERE(LY/DAY)
C**** V(I,5,M3)=SOX*COSZ   ***************OLD CARD REPLACED,**********
      V(I,5,M3)= AMAX1(0.,SOX*COSZ)
C   SAVE SOLAR RADIATION ABSORBED BY ATMOSPHERE(LY/DAY)
        V(I,6,M3)=TDSABS-SG
C   SAVE SOLAR RADIATION ABSORBED BY GROUND(LY/DAY)
        V(I,7,M3)=SG
C   SAVE NET LONG-WAVE RADIATION AT TOP OF MODEL ATMOSPHERE(LY/DAY)
        V(I,8,M3)=RE(1)
C   SAVE NET LONG-WAVE RADIATION AT GROUND(LY/DAY)
        V(I,9,M3)=RE(NLAYP1)
      SHS(J,I)=SG-RE(NLAYP1)
C    *    *    SAVE WIND MAGNITUDE
        V(I,9,11)=WMAG
C
C**** PREDICTION OF GROUND CONDITION
  420 CONTINUE
C     NEW
      WTSTO=WET
      WETIT=WET*3.333333333-.666666666
      WETIT=2.*WETIT
      WET=AMIN1(1.,WETIT)
      IF(WET.LT.0.)WET=0.
C SET DEFAULTS FOR COMP3 TAPE
          V(I,5,M2) = 0.
          V(I,6,M2) = 0.
          V(I,7,M2) = 0.
```

```
         V(I,8,M2) = 0.
         T(I,3,M2) = 0.
      IF(OCEAN) GO TO 650
      IF(SNOW) GO TO 610
      IF(ICE) GO TO 620
      IF(FROST) GO TO 630
      IF(MIXWI) GO TO 640
      EVAL=600.
      CZH=SQRT((.366+.15*WET)*(1.+WET)*2.E-3*SDAY/TWOPI)
      CZH=SQRT((.3+VSM)*(1.+10*VSM)*1.0E-03*SDAY/TWOPI)
      CZH=CZH*(1-ROCK)+ROCK*6.7
      GO TO 650
  610 EVAL=680.
      CZH=2.3
      GO TO 650
  620 EVAL=680.
      CZH=5.1
      GO TO 650
  630 EVAL=680.
      CZH=SQRT((.331+.075*WET)*(2.+2.5*WET)*1.E-3*SDAY/TWOPI)
      CZH=CZH*(1-ROCK)+6.7*ROCK
      GO TO 650
  640 EVAL=680.
      WI=GT(J,I)
      WI
      WI=2.*WI
      WI=WI*1.566666666-.666666666
      WI=2.*WI
      WI=AMIN1(1.,WI)
      WI=AMAX1(0.,WI)
      IF(WET.GT.1.E-5) EVAL=600.+80.*WI/WET
      CZH=SQRT((.276+(.11+.15*WET)*(WET-.5*WI))*(1.+WET-WI+1.25*WI)*
     *  2.E-3*SDAY/TWOPI)

      IF((GT(J,I).LE.1.1) .AND.(LAND).AND.(.NOT.SNOW)) CHZ=CHZ*(1-ROCK)
     1+6.7*ROCK
  650 TEM=0.
      NEW
      WET=WTSTO
      WI=GT(J,I)
      IF(ICE.AND.Z.LT..1) TEM=CTID/HICE
      TGSQ=TG*TG
      DRAD=4.*STBO*TGSQ*TG
      DSQG=5418.*SHG/TGSQ
      TEMP=10.*DRAW*RHOS*SDAY
        NEW BETA TERM
      IF(EVE.GE.1.0E-40)DTRBET=DTRBET/EVE
      IF(EVE.LT.1.0E-40)DTRBET=0
      IF(EVE.GT..9999)DTRBET=0.
      DSQG=DSQG*(1.+DTRBET)
      DTRBET=0
      TERM1 = SG*NHOCAN
      TERM2 = -CP*TEMP*DTS
      IF(IGVET.EQ.13) TERM2 = TERM2 * 1.5
      TERM3 = -EVAL*EVE*TEMP*DSHS
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C**** IF(FHAJ)TERM3=TERM3*.25     ********************************       HYD05510
      TERM4 = TEM*(TICE-TG)                                              HYD05520
      TERM5 = -FF(NLAYP1)*RHOGAN                                         HYD05530
      DENOM = SDAY*CZH/DTC3 + DRAD - TEM + TEMF*EDV*(CF/(DRAW+EDV)+      HYD05540
     1 EVAL*EVE*DSCG/(EVACO+EDV))                                        HYD05550
      RADTRM=SHS(J,I)                                                    HYD05560
      GT(J,I)=TG+(RADTRM+TERM2+TERM3+TERM4)/DENOM                        HYD05570
      IF ( GT(J,I) .GT. 100.) GO TO 775                                  HYD05580
      WRITE (6,670) J,I,GT(J,I)                                          HYD05590
      WRITE (6,774) J,I,(TL(L),L=1,NLAY),TLF(NLAYP1),TG                  HYD05600
  670 FORMAT( 10X,'***** J I GT(J,I) *****',2I5,E15.7//)                 HYD05610
  774 FORMAT(1X,2I3,11E11.3)                                             HYD05620
  775 CONTINUE                                                           HYD05630
C    SAVE EVAPORATION, SENSIBLE HEAT FLUX, AND CONDUCTION                HYD05640
C    THROUGH SEA ICE(LY/DAY)                                             HYD05650
       V(I,3,M3)=-TERM3                                                  HYD05660
       V(I,4,M3)=-TERM2                                                  HYD05670
       V(I,2,M3)= TERM4                                                  HYD05680
C SAVE GROUND TEMPERATURE ADJUSTMENTS                                    HYD05690
         V(I,5,M2) = TERM1/DENOM                                         HYD05700
         V(I,6,M2) = TERM2/DENOM                                         HYD05710
         V(I,7,M2) = TERM3/DENOM                                         HYD05720
         V(I,8,M2) = TERM4/DENOM                                         HYD05730
         T(I,3,M2) = TERM5/DENOM                                         HYD05740
  690 CONTINUE                                                           HYD05750
C                                                                        HYD05760
C                                                                        HYD05770
C                                                                        HYD05780
C                                                                        HYD05790
C                  *******************************************           HYD05800
C                  **********  GROUND WETNESS SECTION-GISS  *********    HYD05810
C                  *******************************************           HYD05820
C                                                                        HYD05830
C                                                                        HYD05840
C                                                                        HYD05850
      SNFLX=TERM2*6.9444444444E-04                                       HYD05860
      SNFLX=-SNFLX                                                       HYD05870
      RADTRM=SHS(J,I)                                                    HYD05880
      RNIT=RADTRM*6.9444444444E-04                                       HYD05890
      ETFLX=TERM3*6.9444444444E-04                                       HYD05900
      ETFLX=-ETFLX                                                       HYD05910
      IF(OCEAN)ETFLX=V(I,3,M3)*6.9444444444E-04                          HYD05920
      IF(OCEAN)SNFLX=V(I,4,M3)*6.9444444444E-04                          HYD05930
      GNFLX=RNIT-SNFLX-ETFLX+TERM4*6.9444444444E-04                      HYD05940
      E6DT=DSHS*EVE*DTC3*DRAW*RHOS*10.0                                  HYD05950
C                                                                        HYD05960
C                                                                        HYD05970
C                                                                        HYD05980
      WETR=WET                                                           HYD05990
      SNR=0.                                                             HYD06000
      WIR=0.                                                             HYD06010
      TGR=TG                                                             HYD06020
 2550 RAIN=0.                                                            HYD06030
      SNFAL=0.                                                           HYD06040
      FREEZ=0.                                                           HYD06050
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```
      RUNOFF=0.
      SMELT=0.
      FLDRK=0.
      DRNG=0.
      RUNOVV=0.
C     NEW
C     NEW
C
      IF(OCEAN)GO TO 2680
C
      TGR=GT(J,I)
      IF(TOTALP.LT..0)TOTALP=0.
      IF(TLE(NLAYP1).LE.TICE)SNFAL=TOTALP    *100.
      IF(TLE(NLAYP1).GT.TICE) RAIN=TOTALP    *100.
      ISNR = IFIX(GW(J,I))
      SNR=FLOAT(ISNR)/1000.0
      IF(SNR.LT..001) SNR=0.
      SNR1=SNR+SNFAL
      SNR=SNR1-EGDT
      IF(SNR1.LE.0.) GO TO 2650
      IF(SNR.LE.0.)     GO TO 2650
      IF(TGR.LE.TICE)GO TO 2600
      SMELT=CZH*(TGR-TICE)/80.
      SMELT=AMIN1(SMELT,SNR)
      TGR=TGR-80.*SMELT/CZH
      SNR=SNR-SMELT
      IF(ICE) GO TO 2670
C
C
C     SOIL MOISTURE AND FREEZING
C
C
C     SNOW COVERED LAND
C
C
C     NEW
2600  CONTINUE
      WETR=WET+(RAIN+SMELT)/WGM
      RUNOFF=AMAX1(0.0,WETR-1.)
      WETR=WETR-RUNOFF
      GO TO 2680
C     NEW
C
C     SNOW  FREE LAND
C
 2650 SNR=0.
      IF(ICE)GO TO 2670
C     NEW
      IF(RAIN.LT.0.)RAIN=0.0
      IF(RAIN.LE.1.E-60)GO TO 5140
      ADINF=1.25*(2.*WET-.2)-.5
      EEFACT=2.*FILTF*EXP(-1.75*(ADINF-.5))
      IF(RAIN.GE.EEFACT)RUNOFF=RAIN-.5*EEFACT
      IF(RAIN.LT.EEFACT)RUNOFF= .5*RAIN*RAIN/EEFACT
 5140 CONTINUE
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      ADDW=RAIN-RUNOFF                                                  HYD06610
      ADDW=ADDW*(1.-ROCK)                                               HYD06620
      ECAR=E6DT/(1.- RC(K))                                             HYD06630
      WETR=WET+(ADDW-ECAR)/WGM                                          HYD06640
      RUNOVV=ROCK*RAIN                                                  HYD06650
      RUNOFF=RUNOVV+(1-ROCK)*RUNOFF                                     HYD06660
      DRNG=0.05*AMAX1(0.0,WETR-.5)                                      HYD06670
      WETR=WETR-DRNG                                                    HYD06680
C     NEW                                                               HYD06690
      IF(WETR.GT.1.)WETR=1.                                             HYD06700
      IF(WETR.LT.0.)WETR=0.                                             HYD06710
      IF(FROST)TGR=TGR+80.*ADDW/CZH                                     HYD06720
      IF(.NOT.MIXWI) WI=0.                                              HYD06730
      IF(FROST)WI=WETR                                                  HYD06740
      IF(.NOT.(MIXWI.OR.(FROST.AND.TGR.GT.TICE).OR.(TG.GT.TICE.AND.     HYD06750
     1       TGR.LT.TICE)))GO TO 2680                                   HYD06760
      FREEZ=CZH*(TICE-TGR)/80./WGM                                      HYD06770
      WIR=WI+FREEZ                                                      HYD06780
      IF(WIR.GT.WETR)WIR=WETR                                           HYD06790
      IF(WIR.LT.0.)WIR=0.                                               HYD06800
      FREEZ=WIR-WI                                                      HYD06810
      TGR=TGR+80.*FREEZ*WGM/CZH                                         HYD06820
C                                                                       HYD06830
C          ICE                                                          HYD06840
C                                                                       HYD06850
C        ICE                                                            HYD06860
C                                                                       HYD06870
C                                                                       HYD06880
      GO TO 2680                                                        HYD06890
 2670 TGR=AMIN1(TGR,TICE)                                               HYD06900
      WETR=1.                                                           HYD06910
2680  IF(IGVET.GE.10) GT(J,I) =. TGR                                    HYD06920
      IF(WIR.GT..0.AND.WIR.LT.WETR) GT(J,I) = WIR                       HYD06930
      SNR = AMIN1(SNR,30.0)                                             HYD06940
      ISNR = IFIX(AMAX1(0.,SNR)*1000.)                                  HYD06950
      IF(IGVET.GE.20) GW(J,I) = FLOAT(ISNR) + 0.50*WETR                 HYD06960
C*****SAVE GROUND WETNESS,RUNOFF,SMELT                                  HYD06970
      T(I,1,M3) = GW(J,I)                                               HYD06980
      T(I,2,M3) = SMELT                                                 HYD06990
      T(I,3,M3) = RUNOFF                                                HYD07000
      T(I,4,M3) = GT(J,I)                                               HYD07010
      T(I,5,M3) = TOTALP*100.                                           HYD07020
      TGN=GT(J,I)-TICE                                                  HYD07030
      IF(RSURFF.LT..01)TGM=TGM+6                                        HYD07040
      IF(TGN.LT.-270.)TGN=GT(J,I)                                       HYD07050
      TPMN=4.*GW(J,I)                                                   HYD07060
      XRS=RHS                                                           HYD07070
      PCTALP=RAIN                                                       HYD07080
      GWSWCH=AMOD((TAL-TAUI+GSW)/GSW,1.).LT..0001                       HYD07090
      IF(OCEAN)GWSWCH=.FALSE.                                           HYD07100
      IF(J.LE.16)GWSWCH=.FALSE.                                         HYD07110
      IF(J.GE.37)GWSWCH=.FALSE.                                         HYD07120
      IF(I.GE.48) GWSWCH=.FALSE.                                        HYD07130
      IF(GWSWCH.AND.(I/ITC*ITC.EQ.I.AND.(J-1+ITC)/ITC*ITC.EQ.J+ITC-1))  HYD07140
     1 GO TO 8065                                                       HYD07150
```

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      IF(TAU.EQ.TAUI.AND.I.GE.13.AND.I.LE.22.AND.J.GE.31.AND.J.LE.36)   HYD07160
     1 GO TO 8055                                                       HYD07170
      GO TO 8065                                                        HYD07180
 8055 CONTINUE                                                          HYD07190
C     CHANGED UNITS OF PREVAP(MM/HOUR TO CM/HALF HOUR BY DIVD BY 20 10/1HYD07200
      PREVAP=PREVAP/20.                                                 HYD07210
      WRITE(6,2551) J,I,GW(J,I),GT(J,I),FCTALF,FUNOFF,PREVAP,BETA2,     HYD07220
     1ECAR,FILTF,BEFACT,RHOS,DRRN,QSSH,DRAW,DSHS,PLANT ,ROCK,ROFIGW,DTSIHYD07230
 2551 FORMAT(1X,2I3,2X,9(E11.4,2X),/,10X,9(E11.4,2X))                   HYD07240
 2555 FORMAT(///,3X,'J  I    WETNESS/RHOS GRTEMP/DRRN FCTALF/QSSH  FUNCFHYD07250
     1/DRAW   PREVAP/DSHS  BETA2/PLT   ECAR/ROCK     FILTF/ROFIGW EBFACTHYD07260
     2/DTSI',///)                                                       HYD07270
 8065 CONTINUE                                                          HYD07280
C                                                                       HYD07290
C                 ******************************************************HYD07300
C                 **********  GROUND WETNESS SECTION-ENDS  *********    HYD07310
C                 ******************************************************HYD07320
C                                                                       HYD07330
C**** TOTAL HEATING AND MOISTURE ADJUSTMENT                             HYD07340
      DO 520 L=1,NLAY                                                   HYD07350
      SH(I,L,KCENT) = SHL(L)                                            HYD07360
C SAVE CHANGE IN TEMPERATURE FROM SOLAR RADIATION HEATING               HYD07370
         T(I,L,M1) = AS(L)*COE(L)                                       HYD07380
C SAVE CHANGE IN TEMPERATURE FROM LONG-WAVE RADIATION HEATING           HYD07390
         SH(I,L,M1) = (RE(L+1)-RE(L))*CCE(L)                            HYD07400
520   T(I,L,KCENT) = TL(L)+(AS(L)+RE(L+1)-RE(L))*CCE(L)                 HYD07410
      TS(J,I)=TLE(NLAYP1)                                               HYD07420
      SDOT(J,I,1) = AMIN1(SDOT(J,I,1),TS(J,I))                          HYD07430
      SDOT(J,I,2) = AMAX1(SDOT(J,I,2),TS(J,I))                          HYD07440
  810 IMINC=I                                                           HYD07450
      RETURN                                                            HYD07460
      END                                                               HYD07470
```

```
      DIMENSION    LAT(46),FLUXC(8,14,12)
      COMMON       PHIS(08,14),FD(08,14),TOPOG(08,14),SINL(46),COSL(46)
      COMMON
     $             PC(8,14),TSC(8,14),SHSC(8,14),GTC(8,14),GWC(8,14),
     $             UC(8,14,3),VC(8,14,3),TC(8,14,3),SHC(8,14,3),PLK(10),
     $             SGC(8,14),US(08,14),VS(08,14)
      COMMON
     *          PLE(10), TLE(10), RH(10),TH(10),DSIG(10),SHL(10),
     *          SHLE(10),RE(10),SH(8,14,3)    ,PL(10),
     *          GT(08,14),SHS(08,14),TL(10),
     *          SLBEDO(08,14), TS(08,14), GW(08,14),ROK(08,14),
     *          IWR(10),SIGE(10),SIG(10)
      COMMON
     *             RHS,DTS,CD,EDV,ZLN,DRAW,PREVAP,PLANT,EVE,E6DT,
     *RHOS,CZH,DTRBET,TERM1,TERM2,TERM3,TERM4,TERM5, DENOM,RADTRM,
     *             SNFAL,RAIN,OVER,WETR,WET,TAU,WMAG,ELE
      DIMENSION    PLTGTC(200),PLTGT(200),PLTGWC(200),PLTGW(200),
     1             PLTSHL(200),PLSHE(200),PLTX(200),PLTTS(200),
     2             PLTPE(200),PLTAE(200),PLTEVE(200),PLIRGS(200),
     3             PLEGCM(200),PLT9TG(200),PAEGO(200)
      LOGICAL*1 STAR/'*'/,PLUS/'+'/,POUND/'#'/, CROSS/'X'/,PERIOD/'.'/
      LOGICAL OCEAN,SNOW,ICE,LAND,MIXWI,FROST,GCM
      LOGICAL UCLA,UCNI,UCNII,UCNJJA,ASSIM,TINPT,VALBFG
      LOGICAL WETCEL,AVCELL,DRYCEL,LOG8,UCLAVW,VRP4,GDH
      REAL*4 KAPA
      INTEGER*2 SLBEDO
      QSAT(X,Y) = .622*(10.**(9.4051-2353./X))/Y
C
C                                      REVISED MODEL STARTED 1/78
C                                      E CMS HYDRO NEW AT GSFC
C
C                  DATE      CORRECTIONS
C
C                            STEP 1: DESIGN OF EXPERIMENT
C
C                A SET MODEL LOGICAL PARAMETERS
      GCM=.TRUE.
      GCM=.FALSE.
```

```
C                                                                       OLM00390
      UCLA=.FALSE.                                                      OLM00400
      UCLA=.TRUE.                                                       OLM00410
      UCLAVW=.FALSE.                                                    OLM00420
      UCLAVW=.TRUE.                                                     OLM00430
      UCNI=.TRUE.                                                       OLM00440
      UCNI=.FALSE.                                                      OLM00450
      UCNJJA=.FALSE.                                                    OLM00460
      UCNII=.TRUE.                                                      OLM00470
      UCNII=.FALSE.                                                     OLM00480
      ASSIM=.FALSE.                                                     OLM00490
C                  TINPT: TRUE IF SURFACE WD SPEED INFO IS AVAILABLE    OLM00500
C                  ON INPUT DATA TAPE                                   OLM00510
      TINPT=.FALSE.                                                     OLM00520
      LOG8=.FALSE.                                                      OLM00530
      LOG8=.TRUE.                                                       OLM00540
C                  LOG8 TRUE, OLM WILL READ AND USE TAPE VARIABLES,     OLM00550
C                  GWC,GTC, EVERY TIME STEP                             OLM00560
      VALBFG=.TRUE.                                                     OLM00570
C                                                                       OLM00580
      WETCEL =.FALSE.                                                   OLM00590
      WETCEL=.TRUE.                                                     OLM00600
      AVCELL=.TRUE.                                                     OLM00610
      AVCELL=.FALSE.                                                    OLM00620
      DRYCEL=.TRUE.                                                     OLM00630
      DRYCEL=.FALSE.                                                    OLM00640
      VRP4=.TRUE.                                                       OLM00650
      VRP4=.FALSE.                                                      OLM00660
      GDH=.TRUE.                                                        OLM00670
      GDH=.FALSE.                                                       OLM00680
C                                                                       OLM00690
C                                                                       OLM00700
C                B PROGRAM CONSTANTS                                    OLM00710
C                                                                       OLM00720
      NLAY = 9                                                          OLM00730
      NLAYP1 = NLAY + 1                                                 OLM00740
      JMIN=1                                                            OLM00750
      JMAX=8                                                            OLM00760
      IMAX=14                                                           OLM00770
```

```
      IMIN=1                                                            OLM00780
C                                                                       OLM00790
      JMINUS=30                                                         OLM00800
      JMAXUS=37                                                         OLM00810
      IMINUS=12                                                         OLM00820
      IMAXUS=25                                                         OLM00830
C                                                                       OLM00840
      NLAYM1=NLAY-1                                                     OLM00850
      JMP=JMAX-1                                                        OLM00860
      INC=IMIN                                                          OLM00870
      JNC=1                                                             OLM00880
      IM=IMAX                                                           OLM00890
      J1P=JMIN+1                                                        OLM00900
      JMPP1=JMP+1                                                       OLM00910
C                                                                       OLM00920
C                 C DO LOOP PARAMETERS FOR SPECIFIC CELL LOCATIONS      OLM00930
C                                                                       OLM00940
      I1 = IMIN+1                                                       OLM00950
      I2 = IMAX                                                         OLM00960
      I3 = INC                                                          OLM00970
      J1 = JMIN                                                         OLM00980
      J2 = JMAX-1                                                       OLM00990
      J3 = JNC                                                          OLM01000
C                                                                       OLM01010
      SIGE(1)=0.                                                        OLM01020
      DO 70 L=1,NLAY                                                    OLM01030
      DSIG(L)=.11111111                                                 OLM01040
      SIGE(L+1)=SIGE(L)+DSIG(L)                                         OLM01050
   70 SIG(L)=.5*(SIGE(L)+SIGE(L+1))                                     OLM01060
C                                                                       OLM01070
      RGAS=287.                                                         OLM01080
      KAPA=.286                                                         OLM01090
      GRAV = 9.8                                                        OLM01100
      TICE = 273.16                                                     OLM01110
      SDAY= 86.4E+3                                                     OLM01120
      TWOPI = 2.*3.1416                                                 OLM01130
      PI=3.141592654                                                    OLM01140
      DPI=PI                                                            OLM01150
      CTID = 432.                                                       OLM01160
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      HICE = 300.                                                       OLM01170
      STBO = 1.17E-7                                                    OLM01180
      CP = .24                                                          OLM01190
      CLH=600./.24                                                      OLM01200
      GAMFAC = 5418*CLH                                                 OLM01210
C                                                                       OLM01220
C                                STEP 2: PARAMETER SPECIFICATION        OLM01230
C                                                                       OLM01240
C                A VAR THAT ARE A FUNCTION OF TIME STEP                 OLM01250
C                                                                       OLM01260
      DTC3 = 1800.                                                      OLM01270
      NHOGAN=1                                                          OLM01280
      IF(ASSIM) DTC3=60.*60.*3.                                         OLM01290
      IF(ASSIM) NHOGAN=1                                                OLM01300
C                  ASSIM HAS A 3 HOUR TIME INTEFVAL                     OLM01310
      COEFS=GRAV*DTC3/DSIG(NLAY)                                        OLM01320
C                                                                       OLM01330
C                B DATA SPECIFICATION FOR INITIAL RUNS                  OLM01340
C                                                                       OLM01350
C     TOTALP = 0.                                                       OLM01360
      MONTH=8                                                           OLM01370
      IGVET=15                                                          OLM01380
      IGVET=25                                                          OLM01390
      IGVET=23                                                          OLM01400
      PTROP=10.                                                         OLM01410
      ED=10.                                                            OLM01420
C                                                                       OLM01430
C                C INITIALIZATION OF CELL VARIABLES                     OLM01440
C                                                                       OLM01450
C                  ROK=1: OCEAN, 2:LOAMY SOIL, 3:SANDY SOIL             OLM01460
      READ(5,145)  ((ROK(J,I),J=1,8),I=1,14)                            OLM01470
C                  SLBEDO FOR JULY I527ALBD BUT GCM TAPE USED 14 FOR LANOLM01480
      READ(5,146)  ((SLBEDO(J,I),J=1,8),I=1,14)                         OLM01490
C                  BUT FOR THREE TEST CELLS IT READS PHIS ARRAY         OLM01500
C                  SEE TOPOG PRINT OUT                                  OLM01510
      READ(5,145)  ((PHIS(J,I),J=1,8),I=1,14)                           OLM01520
      DO 148 L=8,MONTH                                                  OLM01530
      DO 148 I=1,14                                                     OLM01540
      READ(5,147) M,(TOPOG(J,I),J=1,8)                                  OLM01550
```

```
  148 CONTINUE                                                          OLM01560
  145 FORMAT(8(F10.5))                                                  OLM01570
  146 FORMAT(8(I2))                                                     OLM01580
  147 FORMAT(I8,8(F9.3))                                                OLM01590
C     READ(20) SLBEDO,PHIS,TOPOG                                        OLM01600
C                                                                       OLM01610
C                D SET SUMS FOR ALL AVERAGES = TO 0.                    OLM01620
      AVGT=0.                                                           OLM01630
      SUMAV=0.                                                          OLM01640
      AVTS=0.                                                           OLM01650
      AVGW=0.                                                           OLM01660
      AVGTC=0.                                                          OLM01670
      AVTSC=0.                                                          OLM01680
      AVGWC=0.                                                          OLM01690
C                                                                       OLM01700
C                E INITIAL DATA TAPE READ                               OLM01710
C                                                                       OLM01720
      READ(08,95) TAU,PC,TSC,SHSC,GTC,GWC,UC,VC,TC,SHC,FLUXC            OLM01730
   95 FORMAT(026(255A4))                                                OLM01740
C                                                                       OLM01750
C                                                                       OLM01760
      HOUR = TAU                                                        OLM01770
      NHH=10                                                            OLM01780
      NHH=96                                                            OLM01790
      TINC=.5                                                           OLM01800
      IF(ASSIM) TINC=3.0                                                OLM01810
C                                                                       OLM01820
      DO 200 IHH = 1,NHH                                                OLM01830
      HOUR= HOUR+TINC                                                   OLM01840
C                                                                       OLM01850
C                                                                       OLM01860
C                F BEGIN CELL LOOP OF MODEL                             OLM01870
C                       VARIABLE LOCATION                               OLM01880
C        --------------------------------------------------             OLM01890
C                                                                       OLM01900
C                                                                       OLM01910
C        - - - - - - - - - - - - - - - - - - - - - - - - - -TL,T(LAYER 9OLM01920
C                                                                       OLM01930
C                                                                       OLM01940
```

```
C        --------------------------------------------------TS,TLE,PLE  OLM01950
C                                                                      OLM01960
C        ************************************************* GT,P ,TS,SHS,OLM01970
C                                                                      OLM01980
C        OLD       NEW       EQUIVALENT     SOURCE    NAME             OLM01990
C                                                                      OLM02000
C    ******************************************************************OLM02010
C                                                                      OLM02020
C        NOTE 1    NOTE 1    PC(8,14)       TAPE      P(J,I) = PI = PS-POLM02030
C        TS(10,10) TS(8,14)  TSC(8,14)      TAPE      SURFACE TEMPERATUROLM02040
C       SHS(10,10) SHS(10,10) SHSC(8,14)    TAPE      NET RADIATION(LY/DOLM02050
C        GT(10,10) GT(8,14)  GTC(8,14)      TAPE      GROUND TEMPERATUREOLM02060
C        GW(10,10) GW(8,14)  GWC(8,14)      TAPE      GROUND WETNESS    OLM02070
C                 UC(8,14,3) UC(8,14,3)     TAPE      X VEL COMPONENT(M/OLM02080
C                 VC(8,14,3) VC(8,14,3)     TAPE      Y VEL COMPONENT(M/OLM02090
C        NOTE 2    NOTE 2    TC(8,14,3)     TAPE      LAYER TEMPERATURE OLM02100
C        SH(10)   SH(8,14,3) SHC(8,14,3)    TAPE      SPEC HUM OF LAYER OLM02110
C        TLE(10)   TLE(10)                  STEP 7    T(L) OF INTER L-1,OLM02120
C        RH(10)    RH                       STEP 6    RELATIVE HUMIDITY OLM02130
C        PLE(10)   PLE(10)                  STEP 4A   PR OF INTER FACE,LOLM02140
C        TH(10)    TH(10)                   STEP 7    POTENTIAL TEMPERATOLM02150
C        DSIG(10)  DSIG(10)                 PROG CONST.=1/NLAY=.111111 OLM02160
C    SLBEDO(10,10) SLBEDO(8,14)              SPECIFIED EARTH ALBEDO FROMOLM02170
C                                                                      OLM02180
C             NOTE 1: PL & PLE ARE SPECIFIED IN STEP 4A FROM PC        OLM02190
C             NOTE 2 TL IS SPECIFIED IN STEP 4B IF GCM INPUT NOT AVAILABOLM02200
C                                                                      OLM02210
C                  DO ONE CELL FOR NOW 10/22/77                        OLM02220
      IF(WETCEL) I1C=12                                                OLM02230
      IF(WETCEL) J1C=7                                                 OLM02240
      IF(AVCELL) I1C=6                                                 OLM02250
      IF(AVCELL) J1C=3                                                 OLM02260
      IF(DRYCEL) I1C=4                                                 OLM02270
      IF(DRYCEL) J1C=4                                                 OLM02280
      J3C=1                                                            OLM02290
      I3C=1                                                            OLM02300
      I2C=I1C                                                          OLM02310
      J2C=J1C                                                          OLM02320
      NCELL=0                                                          OLM02330
```

```
C
      DO 300 I=I1C,I2C,I3C
      DO 300 J=J1C,J2C,J3C
C
      NCELL=NCELL+1
C
C                G  DO LOOP READ
      IF(IHH.GT.1) READ(08,95) TAU,PC,TSC,SHSC,GTC,GWC,UC,VC,TC,SHC
     *,FLUXC
C
      IF(NCELL.EQ.1)
     1CALL SUBFWD(NLAY,NLAYM1,JMP,INC,IM,J1P,JMPP1,TINPT,ASSIM)
C
C                H SOLAR DECLINATION CALCULATION
C
      IF(NCELL.EQ.1)
     1CALL SDET(PI,DPI,COSD,SIND,ROT,DLON,ASSIM,IHH,LAT,JDAY,NCELL,
     2TOFDAY)
C
C
C                I OFFLINE INTERFACE CONSIDERATIONS
C
C                  INITIALIZE GW(J,I) WITH GWC(J,I) VALUES
C
      IF(IHH.EQ.1)  GW(J,I)=GWC(J,I)
C                  GTC READ TWICE BECAUSE NET RADIATION NOT AVAILABLE IH
      IF(GTC(J,I).LT.2.)  GTC(J,I)=TICE
      IF(IHH.LE.2)  GT(J,I)=GTC(J,I)
                   TS(J,I)=TSC(J,I)
      IF(LOG8.AND.UCLA)  GW(J,I)=GWC(J,I)
      IF(LOG8)  GT(J,I)=GTC(J,I)
C
C                J ZENITH ANGLE CALCULATION
C
      IUS=IMINUS+I-1
      JUS=JMINUS+J-1
      HACOS=COSD*COS(ROT+(IUS-1)*DLON)
      COSZ=SINL(JUS)*SIND+COSL(JUS)*HACOS
      Z =ARCOS(COSZ)
```

```
      SINA=COSD*SIN(ROT+(IUS-1)*DLON)/SIN(Z)                            OLM02730
      CHOUR=TOFDAY-(37.-IUS)*24./72.                                    OLM02740
      IF(CHOUR.LE.0.) CHOUR=CHOUR+24.                                   OLM02750
      IF(NCELL.EQ.1) WRITE(6,152) COSZ,SINA,CHOUR                       OLM02760
  152 FORMAT(10X,'SOLAR ZENITH ANGLE, COSZ =',E12.4,5X,'AZIMUTH ANGLE(+WOLM02770
     1,-E OF S), SINA = ',E12.4,07X,'LOCAL CELL HOUR = ',F6.2)          OLM02780
C                                                                       OLM02790
C                           STEP 3: SURFACE SPECIFICATIONS              OLM02800
C                                                                       OLM02810
C                  3A SURFACE CONDITION                                 OLM02820
C                                                                       OLM02830
      OCEAN=TOPOG(J,I).GT.1.                                            OLM02840
      ICE=TOPOG(J,I).LT.-9.9E5                                          OLM02850
      LAND=.NOT.(ICE.OR.OCEAN)                                          OLM02860
      IF(IHH.EQ.1) GO TO 54                                             OLM02870
   53 SNOW=LAND.AND.GW(J,I).GT.1.00                                     OLM02880
      IF(IGVET.EQ.24) GO TO 52                                          OLM02890
      SNOW = LAND.AND.(GW(J,I).GT.1.0.OR.SLBEDO(J,I).GE.40)             OLM02900
      IF(SNOW)GW(J,I)=AMAX1(10.5,GW(J,I))                               OLM02910
      GO TO 52                                                          OLM02920
   54 SRH=85.*GW(J,I) +15.                                              OLM02930
      IF(ROK(J,I).EQ.1.) GO TO 55                                       OLM02940
      IF(ROK(J,I).EQ.2.) GO TO 44                                       OLM02950
      IF(ROK(J,I).EQ.3.) GO TO 42                                       OLM02960
   44 FC=.25                                                            OLM02970
      PWP=.10                                                           OLM02980
      C1=1.0                                                            OLM02990
      C2=1.0                                                            OLM03000
      PORE=.5                                                           OLM03010
      SOILLR=100.                                                       OLM03020
      WCAS=PORE*SOILLR                                                  OLM03030
      GO TO 49                                                          OLM03040
   42 FC=.09                                                            OLM03050
      PWP=.025                                                          OLM03060
      C1=1.0                                                            OLM03070
      C2=1.0                                                            OLM03080
      PORE=.5                                                           OLM03090
      SOILLR=050.                                                       OLM03100
      WCAS=PORE*SOILLR                                                  OLM03110
```

```
   49 GW(J,I)=SRH*(FC*C1-PWP*C2)/100.  +PWP*C2                         OLM03120
   55 GW(J,I)=GW(J,I)/2.                                               OLM03130
      IF(OCEAN) GW(J,I) =.5                                            OLM03140
      IF(IGVET.EQ.24) GO TO 21                                         OLM03150
      IF(OCEAN) GO TO 52                                               OLM03160
C                                                                      OLM03170
C                         REF T&K CMP12980                             OLM03180
      PI180 = PI/180.                                                  OLM03190
      SNOWN=(60.-15.*COS(.9863*(JDAY-24.668)*PI180))*PI180             OLM03200
      SNOWS=SNOWN-2.*PI/3.                                             OLM03210
      JNP=46                                                           OLM03220
C     IF(LAT(JUS).GE.SNOWN)GW(J,I)=GW(J,I)+INT((LAT(JUS)-SNOWN)/(LAT(JNPOLM03230
C    *)-SNOWN)*3.E4)                                                   OLM03240
C     IF(LAT(JUS).LE.SNOWS) GW(J,I)=GW(J,I)+INT((LAT(JUS)-SNOWS)/(LAT(1)OLM03250
C    *-SNOWS)*3.E4)                                                    OLM03260
      GO TO 52                                                         OLM03270
   21 IF(SLBEDO(J,I).LE.39) GO TO 52                                   OLM03280
      GW(J,I)=2.00E03 +.5                                              OLM03290
      IF(SLBEDO(J,I).LT.70.) GW(J,I)=1.0E03 +.5                        OLM03300
      IF(SLBEDO(J,I).LT.50) GW(J,I)=.5E03+.5                           OLM03310
      IF(ICE) GW(J,I) = 30.E03+.5                                      OLM03320
      IF(JUS.LE.9.AND.LAND) GW(J,I)=30.0E03+.5                         OLM03330
      SNOW = LAND.AND.GW(J,I).GT.1.01                                  OLM03340
   52 IF(VALBFG) GO TO 56                                              OLM03350
      SLBEDO(J,I)=14                                                   OLM03360
      IF(OCEAN) SLBEDO(J,I)=7.                                         OLM03370
      SNOW = LAND.AND.(GW(J,I).GT.1.0.OR.SLBEDO(J,I).GE.40)            OLM03380
      IF(SNOW.OR.ICE) SLBEDO(J,I) = 70.                                OLM03390
   56 RSURF=.01*SLBEDO(J,I)                                            OLM03400
      IF(IGVET.NE.24.OR.GW(J,I).LT.1.01) GO TO 66                      OLM03410
      SNOTEM=SQRT((GW(J,I)-.5)/1000.)                                  OLM03420
      RSURF=.5*SNOTEM                                                  OLM03430
      IF(SNOTEM.LT.1.) RSURF=RSURF+.01*SLBEDO(J,I)*(1.-SNOTEM)         OLM03440
      RSURF = AMIN1(RSURF,.8)                                          OLM03450
   66 WET=AMIN1(1.,(AMOD(GW(J,I),1.)*2))                               OLM03460
C                  IF VALBFG IS T MUST HAVE FOLLOWING CARD 11/2/77     OLM03470
      SNOW = LAND.AND.(GW(J,I).GT.1.0.OR.SLBEDO(J,I).GE.40)            OLM03480
      LAND=LAND.AND..NOT.SNOW                                          OLM03490
      MIXWI=GT(J,I).LE.1.1.AND.(LAND.OR.SNOW)                          OLM03500
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      FROST=LAND.AND.(GT(J,I).LE.TICE).AND..NOT.MIXWI                   OLM03510
C                                                                       OLM03520
C                    SURFACE ELEVATION                                  OLM03530
C                                                                       OLM03540
      IF(OCEAN.AND.(PHIS(J,I).EQ.0.))   Z=0.                            OLM03550
      IF(.NOT.OCEAN)  Z=PHIS(J,I)/GRAV                                  OLM03560
C                                                                       OLM03570
C                 3B SURFACE TEMPERATURE                                OLM03580
C                                                                       OLM03590
      IF(OCEAN)  TG=TOPOG(J,I)                                          OLM03600
      IF(.NOT.OCEAN)  TG=GT(J,I)                                        OLM03610
      IF(MIXWI)  TG=TICE                                                OLM03620
      IF(.NOT.LAND)  WET=1.0                                            OLM03630
C                                                                       OLM03640
C                 3C SURFACE DRAG COEFFICIENT                           OLM03650
C                                                                       OLM03660
      IMINC=I-1                                                         OLM03670
      WMAG=.5*SQRT(FD(J,I)+FD(J,IMINC)+FD(J+1,I)+FD(J+1,IMINC))         OLM03680
      IF(OCEAN)  CD=AMIN1((1.+.07*WMAG)*.001,.0025)                     OLM03690
      IF(.NOT.OCEAN)  CD= .002+.006*Z/5000.                             OLM03700
C                                                                       OLM03710
      IF(IGVET.EQ.15)  GO TO 71                                         OLM03720
      IF(GDH.AND.OCEAN)  CD=CD*.5                                       OLM03730
      IF(GDH.AND..NOT.OCEAN)  CD=CD*2.0                                 OLM03740
      GO TO 72                                                          OLM03750
   71 CD=.0032*(1.+3.*Z/5000.)                                          OLM03760
      IF(OCEAN)  CD=.10/(ALOG(1.0E06/(5.56/AMAX1(1.,WMAG)-.984+         OLM03770
     1 .00687*WMAG*WMAG)))**2                                           OLM03780
   72 CONTINUE                                                          OLM03790
C                                                                       OLM03800
C                                                                       OLM03810
C                        STEP 4: VERT. ARRAYS FOR SOME VARIABLES        OLM03820
C                                                                       OLM03830
C                 4A PRESSURES                                          OLM03840
C                                                                       OLM03850
      SP=PC(J,I)                                                        OLM03860
C             PC(J,I)=PS-PTROP=PI=P(J,I)=SP                             OLM03870
C             P(J,I)=PTROP+SIG(NLAY)*PT                                 OLM03880
C             PS=PTROP+SIG(10)*(PS-PTROP)=PS                            OLM03890
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C          PS=SP+PTROP=PLE(NLAY+1)                                      OLM03900
      DO 30 L=1,NLAY                                                    OLM03910
      PL(L)=SIG(L)*SP+PTROP                                             OLM03920
      PLE(L)=SIGE(L)*SP+PTROP                                           OLM03930
   30 PLK(L)= PL(L)**KAPA                                               OLM03940
      PLE(NLAY+1)=SP+PTROP                                              OLM03950
C                                                                       OLM03960
C                  4B  TEMPERATURES AND CONVECTIVE ADJUSTMENT           OLM03970
C                                                                       OLM03980
      DO 35 L=1,NLAY                                                    OLM03990
      NC=L-6                                                            OLM04000
      IF(L.LE.6)  TL(L)=TC(J,I,1)-(TC(J,I,2)-TC(J,I,1)*(NLAY-2-L))      OLM04010
   35 IF(L.GE.7)  TL(L)=TC(J,I,NC)                                      OLM04020
      IF(GCM)  GO TO 41                                                 OLM04030
      DO 40 N=1,3                                                       OLM04040
      DO 40 L=2,NLAY                                                    OLM04050
      LM1=L-1                                                           OLM04060
      IF(TL(L-1)/PLK(L-1).GE.TL(L)/PLK(L))  GO TO 40                    OLM04070
      THETA=(TL(LM1)*DSIG(LM1)+TL(L)*DSIG(L))/(PLK(LM1)*DSIG(LM1)+      OLM04080
     *PLK(L)*DSIG(L))                                                   OLM04090
      TL(L-1)=THETA*PLK(L-1)                                            OLM04100
      TL(L)=THETA*PLK(L)                                                OLM04110
   40 TH(L-1)=TL(L-1)/PLK(L-1)                                          OLM04120
   41 TH(NLAY)=TL(NLAY)/PLK(NLAY)                                       OLM04130
C                                                                       OLM04140
C                  4C MOISTURE VARIABLES                                OLM04150
      DO 50 L=1,NLAY                                                    OLM04160
      NC=L-6                                                            OLM04170
      IF(L.LE.6)  SHL(L)=SHC(J,I,1)-(SHC(J,I,2)-SHC(J,I,1)*(NLAY-2-L))  OLM04180
      IF(L.GE.7)  SHL(L)=SHC(J,I,NC)                                    OLM04190
      IF(SHL(L).LE.0.)  SHL(L)=0.                                       OLM04200
   50 CONTINUE                                                          OLM04210
      IF(GCM)  GO TO 175                                                OLM04220
C                                                                       OLM04230
C                            STEP 5                                     OLM04240
C                  VERTICAL DIFFUSION OF HEAT AND MOISTURE(AIR-EARTH    OLM04250
C                  INTERACTION                                          OLM04260
C                                                                       OLM04270
   65 LMIN=NLAYM1                                                       OLM04280
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      DO 80 L=LMIN,NLAY                                                 OLM04290
      LM1=L-1                                                           OLM04300
      DTETA=(TH(LM1)-TH(L))*(PLK(LM1)+PLK(L))*.5                        OLM04310
      DZUP=SP*DSIG(LM1)*RGAS*TL(LM1)/(PL(LM1)*GRAV)                     OLM04320
      DZDN=SP*DSIG(L)*RGAS*TL(L)/(PL(L)*GRAV)                           OLM04330
      EDLE=.2*ED                                                        OLM04340
      TEMP=DTC3*((DSIG(LM1)+DSIG(L))/((DZUP+DZDN)*(DZUP+DZDN)))         OLM04350
      FLE=-2.*EDLE*DTETA*TEMP                                           OLM04360
      TL(LM1)=TL(LM1)+FLE/DSIG(LM1)                                     OLM04370
      TL(L)=TL(L)-FLE/DSIG(L)                                           OLM04380
      TH(LM1)=TL(LM1)/PLK(LM1)                                          OLM04390
      TH(L)=TL(L)/PLK(L)                                                OLM04400
      DSH=SHL(LM1)-SHL(L)                                               OLM04410
      ELE=-2.*EDLE*DSH*TEMP                                             OLM04420
      SHL(LM1)=SHL(LM1)+ELE/DSIG(LM1)                                   OLM04430
   80 SHL(L)=SHL(L)-ELE/DSIG(L)                                         OLM04440
  175 CONTINUE                                                          OLM04450
C                                                                       OLM04460
C                            STEP 6: RELATIVE HUMIDITY                  OLM04470
C                                                                       OLM04480
      DO 90 L=7,NLAY                                                    OLM04490
      TEMP=QSAT(TL(L),PL(L))                                            OLM04500
   90 RH(L)=SHL(L)/TEMP                                                 OLM04510
C                                                                       OLM04520
      IPR=1                                                             OLM04530
      IF(NCELL.EQ.1.AND.IHH.EQ.1)                                       OLM04540
     *             CALL RITE(IWRS,I,J,IHH,HOUR,IPR,                     OLM04550
     *UCLA,UCNI,UCNJJA,UCNII,I2C,J2C,IMAX,JMAX,IMINUS,JMINUS,MONTH)     OLM04560
C                                                                       OLM04570
C                            STEP 7: DETERMINATION OF SURF TEMP         OLM04580
C                                                                       OLM04590
C                A INITIALIZATION                                       OLM04600
C                                                                       OLM04610
      TLE(NLAYP1) =TS(J,I)                                              OLM04620
      PS=PLE(NLAY+1)                                                    OLM04630
      PSK=PS**KAPA                                                      OLM04640
      THG = TS(J,I)/PSK                                                 OLM04650
C                                                                       OLM04660
C                B RH SCALE                                             OLM04670
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      RHS=0.                                                            OLM04680
      IF(WET+RH(NLAY).NE.0) RHS=2.*WET*RH(NLAY)/(WET+RH(NLAY))          OLM04690
C                                                                       OLM04700
C                C BULK AERODYNAMIC COEFF.                              OLM04710
C                                                                       OLM04720
      DTS=TG-TLE(NLAYP1)                                                OLM04730
      IF(DTS.GE.0.) DRAW=CD*(WMAG+SQRT(DTS))                            OLM04740
      IF(DTS.LT.0.) DRAW=CD*WMAG*(WMAG*WMAG)/((WMAG*WMAG) -7.*DTS)      OLM04750
C                                                                       OLM04760
C                D SURFACE DIFFUSION COEFF                              OLM04770
C                                                                       OLM04780
      ZLNCO = .5*DSIG(NLAY)*RGAS/GRAV                                   OLM04790
      SP=(PLE(10)-PL(9))/(1.-17./18.)                                   OLM04800
C                                                                       OLM04810
C                E ORIGINAL FORMULATION FROM TSANG & KARN               OLM04820
C                                                                       OLM04830
      WMAGN=1                                                           OLM04840
      IF(DTS.LT.0.) WMAGN = .2*(WMAG+.01)                               OLM04850
      EDNS=AMIN1(100.,ED*EXP(.32*DTS/WMAGN*WMAGN))                      OLM04860
      FORIG=EDNS                                                        OLM04870
      ZLN = ZLNCO*TLE(NLAYP1)*SP/PS                                     OLM04880
C                           NEW EDNS FORMULATION (1/30/78)              OLM04890
C                           NCAR W/NO COUNTERGRADIENT                   OLM04900
C                                                                       OLM04910
      EDNS=10.+100.*(1.-EXP(1200.*((TH(NLAY)-THG)/ZLN)))                OLM04920
C                      TH(9) GT THG THE FOLLOWING EDNS PREDICTION IS BAOLM04930
      IF(TH(9).GT.THG) EDNS=FORIG                                       OLM04940
C                                                                       OLM04950
      EDV=EDNS/ZLN                                                      OLM04960
C                                                                       OLM04970
C     WRITE(6,7123)                                                     OLM04980
C7123 FORMAT(10X,'EORIG',6X,'EDNS',8X,'TH(9)',8X,'THG')                 OLM04990
C     WRITE(6,7119) EORIG,EDNS, TH(9),THG                               OLM05000
C7119 FORMAT(5X,4(E12.4))                                               OLM05010
C                                                                       OLM05020
C                                                                       OLM05030
      EVE=1.                                                            OLM05040
      IF(LAND.AND..NOT.SNOW)  GO TO 7034                                OLM05050
      GO TO 7235                                                        OLM05060
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  7034 CONTINUE                                                         OLM05070
C                                                                       OLM05080
C                    F EVAPORATION SCALING FACTOR                       OLM05090
C                                                                       OLM05100
       IF(UCNI) EVE=AMIN1(1.,(WET-PWP*C2)/(FC*C1-PWP*C1))               OLM05110
       TEMP=2.*GWC(J,I)                                                 OLM05120
       IF(UCLA) EVE=AMIN1(1.,2.*TEMP)                                   OLM05130
       PLANT=AMIN1( 1.,COSZ/.2588)                                      OLM05140
       IF(COSZ.LT.0) PLANT=0.                                           OLM05150
C                                                                       OLM05160
  7235 CONTINUE                                                         OLM05170
       GO TO 7236                                                       OLM05180
  7237 EVE=1.0                                                          OLM05190
  7236 EVACO=EVE*DRAW                                                   OLM05200
       EVACO=AMAX1(EVACO,1.E-40)                                        OLM05210
       SHSATS=QSAT(TLE(NLAYP1),PS)                                      OLM05220
       SHG=QSAT(TG,PS)                                                  OLM05230
       TEMP=SHSATS/TLE(NLAYP1)                                          OLM05240
       GAMC=ZLN*RHS*9.8*(1.-(1.+CLH*TEMP/KAPA)/(1.+GAMFAC*TEMP/         OLM05250
     *  TLE(NLAYP1)))*KAPA/RGAS                                         OLM05260
       TLE(NLAYP1)=(DRAW*TG+EDV*(TH(NLAY)*PSK-GAMC))/(DRAW+EDV)         OLM05270
       SHLE(NLAYP1)=(EVACO*SHG+EDV*SHL(NLAY))/(EVACO+EDV)               OLM05280
       SHSATS=QSAT(TLE(NLAYP1),PS)                                      OLM05290
       IF(SHLE(NLAYP1).LE.SHSATS)  GO TO           7121                 OLM05300
       GAMS=GAMFAC*SHSATS/TLE(NLAYP1)**2                                OLM05310
       TEMP=(SHLE(NLAYP1)-SHSATS)/(1+GAMS)                              OLM05320
       TLE(NLAYP1)=TLE(NLAYP1)  + TEMP*CLH                              OLM05330
       SHLE(NLAYP1)  = SHLE(NLAYP1)  -TEMP                              OLM05340
  7121 RHOS=PS/(RGAS*TLE(NLAYP1))                                       OLM05350
C                                                                       OLM05360
C                    G  POTENTIAL EVAPORATION(MM/HR)                    OLM05370
C                                                                       OLM05380
       PREVAP=DRAW*RHOS*100.*(QSAT(TG,PS)-SHLE(NLAYP1))*3600.           OLM05390
       IF(PREVAP.LE.0..AND.EVE.LT..999) GO TO 7237                      OLM05400
C                                                                       OLM05410
C                    H POT EVAP USING LOG8 INPUT(MM/HR)                 OLM05420
C                                                                       OLM05430
       T=GTC(J,I)                                                       OLM05440
       DGCM=GTC(J,I)-TSC(J,I)                                           OLM05450
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      WETGCM=GWC(J,I)*2.
      EVCM=AMIN1(1.,2.*WETGCM)
      SGCM=QSAT(T,PS)
      IF(DGCM.GE.0.)  DRCM=CD*(WMAG+SQRT(DGCM))
      IF(DGCM.LT.0.)  DRCM=CD*WMAG*(WMAG*WMAG)/((WMAG*WMAG)-7.*DGCM)
      EVACOG=EVCM*DRCM
      SH10 =(EVACOG*SGCM+EDV*SHL(9))/(EVACOG+EDV)
      DGCMSH=SGCM-SH10
      EGCM=DGCMSH*EVCM*DTC3*DRCM*RHOS*10.
C
C                        STEP 8A:
C           SENSIBLE HEAT(LY/DAY) & EVAPORATION(GR/CM**2/SEC)
C
      DTS=.5*(DTS+TG-TLE(NLAYP1))
      DSHS=SHG-SHLE(NLAYP1)
      IF(DTS.GE.0.)  DRAW=CD*(WMAG+SQRT(DTS))
      IF(DTS.LT.0.)  DRAW=CD*(WMAG**3)/(WMAG**2-7.*DTS)
      FSURF=COEFS*RHOS*DRAW/SP
      TL(NLAY)=TL(NLAY)+FSURF*DTS
      TH(NLAY)=TL(NLAY)/PLK(NLAY)
      SAVSHL=SHL(NLAY)
      SHL(NLAY)=SHL(NLAY)+FSURF*EVE*DSHS
C     SAVSHL=SAVSHL/SHL(NLAY)
      IF(SHL(NLAY).LT.0.)  SHL(NLAY)=0.
C
      IPR=2
                 CALL RITE(IWRS,I,J,IHH,HOUR,IPR,
     *UCLA,UCNI,UCNJJA,UCNII,I2C,J2C,IMAX,JMAX,IMINUS,JMINUS,MONTH)
C
C                       STEP 14: GROUND UPDATE OF MOISTURE AND TEMP
C
      WTSTO=WET
 1405 IF(OCEAN)  GO TO 1490
      IF(SNOW)  GO TO 1410
      IF(ICE)  GO TO 1420
      IF(FROST)  GO TO 1430
      IF(MIXWI)  GO TO 1440
      EVAL=600.
         IF(UCLA)  CZH=((.386+.15*WET)*(1.+WET)*2.E-3*SDAY/TWOPI)**.5
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      GO TO 1450                                                        OLM05850
 1410 EVAL=680.                                                         OLM05860
      CZH=2.3                                                           OLM05870
      GO TO 1450                                                        OLM05880
 1420 EVAL=680.                                                         OLM05890
      CZH=5.1                                                           OLM05900
      GO TO 1450                                                        OLM05910
 1430 EVAL=680.                                                         OLM05920
      CZH=SQRT((.331+.075*WET)*(2.+2.5*WET)*1.E-3*SDAY/TWOPI)           OLM05930
      GO TO 1450                                                        OLM05940
 1440 EVAL=680.                                                         OLM05950
C                                                                       OLM05960
C                A WI CALCULATION                                       OLM05970
C                                                                       OLM05980
      WI=GT(J,I)                                                        OLM05990
 1445 CZH=SQRT((.276+(.11 +.15*WET)*(WET-.5*WI))*(1.+WET-WI+1.25*WI)*   OLM06000
     *  2.E-3*SDAY/TWOPI)                                               OLM06010
 1450 TEM=0.                                                            OLM06020
      WET=WTSTO                                                         OLM06030
      WJ=GT(J,I)                                                        OLM06040
C                                                                       OLM06050
C                B GROUND TEMPERATURE UPDATE                            OLM06060
C                                                                       OLM06070
      IF(ICE.AND.Z.LT..1) TEM=CTID/HICE                                 OLM06080
      TGSQ=TG*TG                                                        OLM06090
      DRAD=4.*STBO*TGSQ*TG                                              OLM06100
      DSQG=5418.*SHG/TGSQ                                               OLM06110
      TEMP=10.*DRAW*RHOS*SDAY                                           OLM06120
C                                                                       OLM06130
C                                                                       OLM06140
C     TERM1 = SG*NHOGAN                                                 OLM06150
      TERM2 = -CP*TEMP*DTS                                              OLM06160
      TERM3 = -EVAL*EVE*TEMP*DSHS                                       OLM06170
      TERM4= TEM*(TICE-TG)                                              OLM06180
C                                                                       OLM06190
C                                 EMIS=.9                               OLM06200
C                                RE(NLAYP1)=(1.17E-7*TG**4)*EMIS        OLM06210
C     TERM5 = -RE(NLAYP1)*NHOGAN                                        OLM06220
          DENOM = SDAY*CZH/DTC3 + DRAD + TEM + TEMP*EDV*(CP/DRAW+EDV) + OLM06230
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     *EVAL*EVE*DSQG/(EVACO+EDV)                                        OLM06240
                SHS(J,I)=SHSC(J,I)*NHOGAN                              OLM06250
C                             SHS(J,I)  =  SG-RE(NLAYP1)               OLM06260
      RADTRM=SHS(J,I)                                                  OLM06270
      GT(J,I)=TG+(RADTRM+TERM2+TERM3+TERM4)/DENOM                      OLM06280
 1490 CONTINUE                                                         OLM06290
 1475 CONTINUE                                                         OLM06300
C                                                                      OLM06310
      IPR=4                                                            OLM06320
C                                                                      OLM06330
                    CALL RITE(IWRS,I,J,IHH,HOUR,IPR,                   OLM06340
     *UCLA,UCNI,UCNJJA,UCNII,I2C,J2C,IMAX,JMAX,IMINUS,JMINUS,MONTH)    OLM06350
C                                                                      OLM06360
C                 C ACTUAL EVAPORATION(CM/HH)                          OLM06370
C                                                                      OLM06380
      E6DT=DSHS*EVE*DTC3*DRAW*RHOS*10.0                                OLM06390
C                                                                      OLM06400
C                 D GROUND MOISTURE UPDATE                             OLM06410
C                                                                      OLM06420
      WETR=WET                                                         OLM06430
      SNR=0.                                                           OLM06440
      WIR=0.                                                           OLM06450
      TGR=TG                                                           OLM06460
 1851 RAIN=0.                                                          OLM06470
      SNFAL=0.                                                         OLM06480
      FREEZ=0.                                                         OLM06490
      OVER=0.                                                          OLM06500
      SMELT=0.                                                         OLM06510
      FLDRK=0.                                                         OLM06520
      DRNG=0.                                                          OLM06530
      RUNOVV=0.                                                        OLM06540
C                                                                      OLM06550
C                                                                      OLM06560
      IF(OCEAN) GO TO 1880                                             OLM06570
      TGR=GT(J,I)                                                      OLM06580
      TOTALP=FLUXC(J,I,3)                                              OLM06590
C                   THEN RAIN INPUT WOULD BE IN CM/SAMPLE TIME         OLM06600
C                   ASSUMES FLC(J,I,3), PRECIP IN MM/SAMPLE TIME       OLM06610
      IF(TOTALP.LT..0) TOTALP=0.                                       OLM06620
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      IF(TLE(NLAYP1).LE.TICE) SNFAL=TOTALP    *100.                         OLM06630
      IF(TLE(NLAYP1).GT.TICE)  RAIN=TOTALP    *100.                         OLM06640
      ISNR = IFIX(GW(J,I))                                                  OLM06650
      SNR=FLOAT(ISNR)/1000.0                                                OLM06660
      IF(SNR.LT..001)  SNR=0.                                               OLM06670
      SNR1=SNR+SNFAL                                                        OLM06680
      SNR=SNR1-E6DT                                                         OLM06690
      IF(SNR1.LE.0.) GO TO 1850                                             OLM06700
      IF(SNR.LE.0.)     GO TO 1850                                          OLM06710
      IF(TGR.LE.TICE) GO TO 1800                                            OLM06720
      SMELT=CZH*(TGR-TICE)/80.                                              OLM06730
      SMELT=AMIN1(SMELT,SNR)                                                OLM06740
      TGR=TGR-80.*SMELT/CZH                                                 OLM06750
      SNR=SNR-SMELT                                                         OLM06760
      IF(ICE) GO TO 1870                                                    OLM06770
C                                                                           OLM06780
C                E SOIL MOISTURE AND FREEZING                               OLM06790
C                                                                           OLM06800
C                          1 SNOW COVERED LAND                              OLM06810
C                                                                           OLM06820
 1800 CONTINUE                                                              OLM06830
      WETR=WET+(RAIN+SMELT)/WCAS                                            OLM06840
      RUNOFF=AMAX1(0.0,WETR-1.)                                             OLM06850
      WETR=WETR-RUNOFF                                                      OLM06860
      GO TO 1880                                                            OLM06870
C                                                                           OLM06880
C                          2 SNOW FREE LAND                                 OLM06890
C                                                                           OLM06900
 1850 SNR=0.                                                                OLM06910
      IF(ICE)GO TO 1870                                                     OLM06920
      RAIN=FLUXC(J,I,3)*100.                                                OLM06930
 1892 E6DT=DSHS*EVE*DTC3*DRAW*RHOS*10.0                                     OLM06940
                 WETR=WET                                                   OLM06950
      IF(RAIN.GT.0.)  OVER=RAIN*(.1+.9*WET**1.5)                            OLM06960
C                            MOISTURE CONTINUITY EQUATION                   OLM06970
      IF(UCLAVW)    WETR=WET + (RAIN-E6DT - OVER)/WCAS                      OLM06980
      IF(WETR.GT.1.) WETR=1.                                                OLM06990
      IF(WETR.LT.0.) WETR=0.                                                OLM07000
      ADDW=(RAIN-E6DT-OVER)/WCAS                                            OLM07010
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      IF(FROST) TGR=TGR+80.*ADDW/CZH                                    OLM07020
      IF(.NOT.MIXWI)  WI=0.                                             OLM07030
      IF(FROST) WI=WETR                                                 OLM07040
      IF(.NOT.(MIXWI.OR.(FROST.AND.TGR.GT.TICE).OR.(TG.GT.TICE.AND.     OLM07050
     1      TGR.LT.TICE))) GO TO 1880                                   OLM07060
      FREEZ=CZH*(TICE-TGR)/80./WCAS                                     OLM07070
      WIR=WI+FREEZ                                                      OLM07080
      IF(WIR.GT.WETR) WIR=WETR                                          OLM07090
      IF(WIR.LT.0.) WIR=0.                                              OLM07100
      FREEZ=WIR-WI                                                      OLM07110
      TGR=TGR+80.*FREEZ*WCAS/CZH                                        OLM07120
      GO TO 1880                                                        OLM07130
C                                                                       OLM07140
C                           3 ICE                                       OLM07150
C                                                                       OLM07160
 1870 TGR=AMIN1(TGR,TICE)                                               OLM07170
      WETR=1.                                                           OLM07180
 1880 IF(IGVET.GE.10)  GT(J,I)  =  TGR                                  OLM07190
      IF(WIR.GT..0.AND.WIR.LT.WETR)  GT(J,I)  =  WIR                    OLM07200
      SNR  =  AMIN1(SNR,30.0)                                           OLM07210
      ISNR  =  IFIX(AMAX1(0.,SNR)*1000.)                                OLM07220
      IF(.NOT.LAND)  GO TO 300                                          OLM07230
      IPR=5                                                             OLM07240
C                                                                       OLM07250
                   CALL RITE(IWRS,I,J,IHH,HOUR,IPR,                     OLM07260
     *UCLA,UCNI,UCNJJA,UCNII,I2C,J2C,IMAX,JMAX,IMINUS,JMINUS,MONTH)     OLM07270
C                                                                       OLM07280
      SUMAV=SUMAV+1                                                     OLM07290
      AVGTC=AVGTC+GTC(J,I)                                              OLM07300
      AVTSC=AVTSC+TSC(J,I)                                              OLM07310
      AVGWC=AVGWC+GWC(J,I)                                              OLM07320
      AVGT  =  AVGT+GT(J,I)                                             OLM07330
      AVTS=AVTS+TLE(10)                                                 OLM07340
      AVGW=AVGW+GW(J,I)                                                 OLM07350
C                  PLOT  DATA                                           OLM07360
C                  GOOD FOR SINGLF CELL ANALYIS ONLY                    OLM07370
      IH2=IHH                                                           OLM07380
 2553 CONTINUE                                                          OLM07390
      PLTGTC(IH2)=GTC(J,I)                                              OLM07400
```

```
      PLTTS(IH2)=TS(J,I)
      PLTGT(IH2)=TG
      PLTGWC(IH2)=SHLE(NLAYP1)
      PLTGW(IH2)=SHL(9)
      PLTSHL(IH2)=EORIG
      PLSHE(IH2)=EDNS
      PLT9TG(IH2)=TH(9)/THG
      PLTX(IH2)=IH2
      IF(UCLA)  PREVAP=(E6DT/EVE)*20.
      PLTPE(IH2)=PREVAP/20.
      PLTAE(IH2)=E6DT
      PLTEVE(IH2)=EVE
      PLEGCM(IH2)=EGCM
      PLIRGS(IH2)=TLE(10)
      PAEGO(IH2)=PLEGCM(IH2)/PLTAE(IH2)
      IF(IH2.GT.95.AND.IH2.LT.101)  IH2=IH2+1
      IF(IH2.GT.95.AND.IH2.LT.101)  GO TO 2553
  300 CONTINUE
  200 CONTINUE
      TEMP=SUMAV
      AVGWC=AVGWC/TEMP
      AVTSC=AVTSC/TEMP
      AVGTC=AVGTC/TEMP
      AVGW=AVGW/TEMP
      AVTS=AVTS/TEMP
      AVGT=AVGT/TEMP
C
      WRITE(6,2571)
 2571 FORMAT(6X,'TIME STEP',1X,'TGC',6X,'TG',7X,'TSC', 3X,'TS(N+1)',2X,
     *'SHLE(10)',4X,'SHL(9)',
     *4X,'EORIG' ,3X,'EDNS',   6X,'PE',8X,'AE',7X,'EVE',6X,'AE-GCM',
     *2X,'EG/EO')
      DO 2574 I=1,NHH
      WRITE(6,2572) I,PLTGTC(I),PLTGT(I),PLTTS(I),PLIRGS(I),PLTGWC(I),
     *PLTGW(I),PLTSHL(I),PLSHE(I),PLTPE(I),PLTAE(I),PLTEVE(I),PLEGCM(I)
     *,PAEGO(I)
 2574 CONTINUE
 2572 FORMAT(8X,I3,2X,4(F7.2,2X),2(F9.7,2X),2(F5.1,2X),4(F8.5,2X),F5.2)
      NHH=IH2-1
```

```
      RNHH=NHH/1.
      VBOT=(AVGT+AVGTC+AVTS)/3.-25.
      VBOT=265.
      VTOP=VBOT+50.
      WRITE(6,2564)  AVGT,AVTS,AVGW,AVGTC,AVTSC,AVGWC
 2564 FORMAT(/,13X,'AV GR TEMP = ',E10.4,14X,'AV SURFACE TEMP = ',E10.4,
     115X,'AV GR WETNESS = ',E10.4,/,3X,'ASSIMILATION GR TEMP = ',E10.4,
     24X,'ASSIMILATION SURFACE TEMP = ',E10.4,5X,'ASSIMILATION GR WETNES
     3S = ',E10.4)
C
      CALL GRDPLT(NHH,0.,RNHH,VBOT,VTOP,PLTX,PLTGTC,PERIOD,1,0)
      CALL GRDPLT(NHH,0.,RNHH,VBOT,VTOP,PLTX,PLTGT,STAR,0,1)
      WRITE(6,2580)
 2580 FORMAT(20X,'PERIOD = INPUT GT',5X,'STAR = CAL GT', /////)
      CALL GRDPLT(NHH,0.,RNHH,VBOT,VTOP    ,PLTX,PLTTS,POUND,1,0)
      CALL GRDPLT(NHH,0.,RNHH,VBOT,VTOP,PLTX,PLIRGS,PLUS,0,1)
      WRITE(6,2595)
 2595 FORMAT(20X,'POUND = INPUT TS',5X,'PLUS = CALCULATED TS')
      CALL GRDPLT(NHH,0.,RNHH,.000,250.,PLTX,PLTSHL,STAR,1,0)
      CALL GRDPLT(NHH,0.,RNHH,.900,1.10,PLTX,PLT9TG,POUND,0,0)
      CALL GRDPLT(NHH,0.,RNHH,.000,250.,PLTX,PLSHE,PLUS,0,1)
      WRITE(6,2585)
 2585 FORMAT(18X,'PLUS = T & K EDNS',      5X,'STARS = NCAR EDNS WHEN
     *TH(9)/THG IS LESS THAN 1.0, UNSTABLE CASE',/////)
      CALL GRDPLT(NHH,0.,RNHH,-.05,0.20,PLTX,PLEGCM,PERIOD,1,0)
      CALL GRDPLT(NHH,0.,RNHH,-.05,0.20,PLTX,PLTPE,PLUS,0,0)
      CALL GRDPLT(NHH,0.,RNHH,-.05,0.20,PLTX,PLTAE,STAR,0,1)
      WRITE(6,2590)
 2590 FORMAT(20X,                                 'STARS = ACTUAL EVAP
     *(CM/HH) ',5X,'PLUS  = POTENTIAL EVAP(CM/HH)',/,20X,'PERIOD = ACTUA
     *L EVAPORATION FROM INPUT TAPE(CM/HH)',/////)
      CALL GRDPLT(NHH,0.,RNHH,.000,1.00,PLTX,PLTEVE,POUND,1,0)
      CALL GRDPLT(NHH,0.,RNHH,0.,2.5,PLTX,PAEGO,PERIOD,0,1)
      WRITE(6,2609)
 2609 FORMAT(20X,'POUND = EVAP SCALING FACTOR',5X,'PERIOD = AEGCM/AEOLM'
     *,/////)
      CALL GRDPLT(NHH,0.,RNHH,0.,.05,PLTX,PLTGWC,STAR,1,0)
      CALL GRDPLT(NHH,0.,RNHH,0.,.05,PLTX,PLTGW,PLUS,0,1)
      WRITE(6,2605)
```

```
 2605 FORMAT(20X,'STAR  = SHLE(10) :TK',5X,'PLUS = SHL(9)',///)         OLM08190
      STOP                                                              OLM08200
      END                                                               OLM08210
      SUBROUTINE SDET(PI,DPI,COSD,SIND,ROT,DLON,ASSIM,IHH,LAT,JDAY,     OLM08220
     1NCELL,TOFDAY)                                                     OLM08230
      DIMENSION    LAT(46),DAYSPM(12),JMONTH(12),AMONTH(2,12)           OLM08240
      COMMON       PHIS(08,14),FD(08,14),TOPOG(08,14),SINL(46),COSL(46) OLM08250
      COMMON                                                            OLM08260
     $             PC(8,14),TSC(8,14),SHSC(8,14),GTC(8,14),GWC(8,14),   OLM08270
     $             UC(8,14,3),VC(8,14,3),TC(8,14,3),SHC(8,14,3),PLK(10),OLM08280
     $             SGC(8,14),US(08,14),VS(08,14)                        OLM08290
      COMMON                                                            OLM08300
     *           PLE(10), TLE(10), RH(10),TH(10),DSIG(10),SHL(10),      OLM08310
     *          SHLE(10),RE(10),SH(8,14,3)   ,PL(10),                   OLM08320
     *          GT(08,14),SHS(08,14),TL(10),                            OLM08330
     *           SLBEDO(08,14), TS(08,14), GW(08,14),ROK(08,14),        OLM08340
     *          IWR(10),STGE(10),SIG(10)                                OLM08350
      COMMON                                                            OLM08360
     *             RHS,DTS,CD,EDV,ZLN,DRAW,PREVAP,PLANT,EVE,E6DT,       OLM08370
     *RHOS,CZH,DTRBET,TERM1,TERM2,TERM3,TERM4,TERM5, DENOM,RADTRM,      OLM08380
     *             SNFAL,RAIN,OVER,WETR,WET,TAU,WMAG,ELE                OLM08390
      LOGICAL OCEAN,SNOW,ICE,LAND,MIXWI,FROST                           OLM08400
      LOGICAL GISSJK,UCLA,UCNI,UCNII,UCNJJA,ASSIM,TINPT                 OLM08410
C                                                                       OLM08420
      INTEGER AMONTH,DAYSPM,DAYSPY                                      OLM08430
C     DATA AMONTH/'JANUARY FEBRUARYMARCH   APRIL   MAY     JUNE    JULY OLM08440
C    *   AUGUST  SEPTEMBEROCTOBER NOVEMBERDECEMBER'/                    OLM08450
C                  JJA PUT COOMENTS ON AMONTH 10/22/77                  OLM08460
      DATA AMONTH/  1,2,3,4,5,6,7,8,9,10,11,12,  1,2,3,4,5,6,7,8, 9,10, OLM08470
     111,12/                                                            OLM08480
      DATA DAYSPM/31,28,31,30,31,30,31,31,30,31,30,31/                  OLM08490
      DATA IDAY0/302/,DAYSPY/365/,LASTM/0/                              OLM08500
      INTEGER*2 SLBEDO                                                  OLM08510
      REAL*4 LAT                                                        OLM08520
C                                                                       OLM08530
      INTFX(XTAU)=INT(XTAU*XINT+.5)                                     OLM08540
      XINT=600.                                                         OLM08550
C                                                                       OLM08560
C                                                                       OLM08570
```

```
      JSP=1
      JSB=1
      JNP=46
      JNB=46
      IF(IHH.GT.1)  GO TO 211
C
      FJEQ=.5*(JSP+JNP)
      DLAT=180/(JNP-JSP)
      DLAT=DLAT*PI/180.
      DO 200 J=JSB,JNB
  200 LAT(J)=DLAT*(J-FJEQ)
      LAT(JSP)=-.5*DPI
      LAT(JNP)=-LAT(JSP)
      DO 210 J=JSB,JNB
      TEMP=LAT(J)
      SINL(J)=SIN(TEMP)
      COSL(J)=COS(TEMP)
C     WRITE(6,30)  J,LAT(J),SINL(J),COSL(J)
C  30 FORMAT(2X,'FOR J =',I4,5X,'LAT(J) = ',E12.4,5X,
C    1 'SINL(J) = ',E12.4,5X,'COSL(J) = ',E12.4)
  210 CONTINUE
C
C
  211 DT=300.
      IF(ASSIM) DT=60.*60.*3.
      DTHR=DT/3600.
      IDTHR=INTFX(DTHR)
      I24=INTFX(24.)
      NSTEP=.5+TAU/DTHR
      ITAU=NSTEP*IDTHR
      TAU=FLOAT(ITAU)/XINT
      IDAY=ITAU/I24
      TOFDAY=FLOAT(ITAU-IDAY*I24)/XINT
      ROT=2*PI*TOFDAY/24.
      IM=72
      DLON =2.*PI/IM
C
      WRITE(6,212) DTHR,IDTHR,NSTEP,ITAU,TAU,IDAY,TOFDAY,ROT,DLON,IHH
  212 FORMAT( /,10X,'DTHR = ',E12.4,5X,'IDTHR = ',I6,5X,'NSTEP = ',
```

```
     1I6,5X, 'ITAU = ',I10,5X,'TAU = ',F12.3,5X, 'IDAY = ',I6,/          OLM08970
     210X,'TOFDAY(Z HRS) = ',E12.4,5X,'ROT = ',F12.4,5X,'DLON = ',E12.4,OLM08980
     3 32X,'STEP = ',I5)                                                  OLM08990
C                                                                         OLM09000
C                                                                         OLM09010
      SOLS=173.                                                           OLM09020
      APHEL=183.                                                          OLM09030
      DECMAX=PI*(23.5/180)                                                OLM09040
      ECCN=.0178                                                          OLM09050
C                                                                         OLM09060
C     CALCULATE CALENDAR                                                  OLM09070
C                                                                         OLM09080
      JYEAR=1+(IDAY+IDAY0-1)/DAYSPY                                       OLM09090
      JDAY=IDAY+IDAY0-DAYSPY*(JYEAR-1)                                    OLM09100
      J=0                                                                 OLM09110
      DO 10 MONTH=1,12                                                    OLM09120
      J=J+DAYSPM(MONTH)                                                   OLM09130
      IF(JDAY.LE.J) GO TO 20                                              OLM09140
   10 CONTINUE                                                            OLM09150
   20 JDATE=JDAY-(J-DAYSPM(MONTH))                                        OLM09160
      JMONTH(1)=AMONTH(1,MONTH)                                           OLM09170
      JMONTH(2)=AMONTH(2,MONTH)                                           OLM09180
C                                                                         OLM09190
      WRITE(6,213) JDAY,JDATE                                             OLM09200
  213 FORMAT(10X,'JDAY = ',I6,5X,'JDATE = ',I6)                           OLM09210
C                                                                         OLM09220
C     CALCUALTE ORBIT POSITION                                            OLM09230
C                                                                         OLM09240
      FDAY=JDAY                                                           OLM09250
      SEASON=(FDAY-SOLS)/DAYSPY                                           OLM09260
      DIST=(FDAY-APHEL)/DAYSPY                                            OLM09270
      DEC=DECMAX*COS(2.*PI*SEASON)                                        OLM09280
      RSDIST=(1.+ECCN*COS(2.*PI*DIST))**2                                 OLM09290
      SIND=SIN(DEC)                                                       OLM09300
      COSD=COS(DEC)                                                       OLM09310
      IF(IHH.EQ.1) WRITE(6,25) SIND,COSD                                  OLM09320
   25 FORMAT( /,5X,'SIND = ',E12.4,5X,'COSD = ',E12.4)                    OLM09330
C                                                                         OLM09340
C                    READ IN TOPOG(J,I) AND CALCULATE  PHIS(J,I)          OLM09350
```

5

```
C                  SEE TSANG AND KARN CODE LISTING PAGE A-23
C                  LINES MAI27100 TO MAI27280
C                  DID NOT INPUT INTO MODEL AT THIS TIME 10/29/77
C
C
      RETURN
      END
      SUBROUTINE SURFWD(NLAY,NLAYM1,JMP,INC,IM,J1P,JMPP1,TINPT,ASSIM)
      DIMENSION    ZM(08,14)
      COMMON       PHIS(08,14),FD(08,14),TOPOG(08,14),SINL(46),COSL(46)
      COMMON
     $             PC(8,14),TSC(8,14),SHSC(8,14),GTC(8,14),GWC(8,14),
     $             UC(8,14,3),VC(8,14,3),TC(8,14,3),SHC(8,14,3),PLK(10),
     $             SGC(8,14),US(08,14),VS(08,14)
      COMMON
     *           PLE(10), TLE(10), RH(10),TH(10),DSIG(10),SHL(10),
     *          SHLE(10),RE(10),SH(8,14,3)   ,PL(10),
     *          GT(08,14),SHS(08,14),TL(10),
     *           SLBEDO(08,14), TS(08,14), GW(08,14),ROK(08,14),
     *          IWR(10),SIGE(10),SIG(10)
      COMMON
     *             RHS,DTS,CD,EDV,ZLN,DRAW,PREVAP,PLANT,EVE,E6DT,
     *RHOS,CZH,DTRBET,TERM1,TERM2,TERM3,TERM4,TERM5, DENOM,RADTRM,
     *             SNFAL,RAIN,OVER,WETR,WET,TAU,WMAG,ELE
      LOGICAL OCEAN,SNOW,ICE,LAND,MIXWI,FROST
      LOGICAL GISSJK,UCLA,UCNI,UCNII,UCNJJA,ASSIM,TINPT
      INTEGER*2 SLBEDO
C
C              SURFACE WIND MAGNITUDE
C
C              CMS: E SUB WIND
C
C                  NOTE FD(J,I) MUST BE CALCULATED AT ALL CELLS FOR
C                  WMAG CALCULATION
      IMIN=INC
      IMAX=IM
      JMIN=J1P-1
      JMAX=JMPP1
C
```

```
      COEF1=(1.-SIG(NLAYM1))/(SIG(NLAY)-SIG(NLAYM1))
      COEF2=(SIG(NLAY)-1)/(SIG(NLAY)-SIG(NLAYM1))
      DO 10 I=IMIN,IMAX
      DO 10 J=JMIN,JMAX
      IF(TINPT) GO TO 10
      US(J,I)=COEF1*UC(J,I,3)+COEF2*UC(J,I,2)
      VS(J,I)=COEF1*VC(J,I,3)+COEF2*VC(J,I,2)
   10 FD(J,I)=US(J,I)**2 +VS(J,I)**2
      RETURN
      END
                    SUBROUTINE RITE(IWRS,I,J,IHH,HOUR,IPR,
     *UCLA,UCNI,UCNJJA,UCNII,I2C,J2C,IMAX,JMAX,IMINUS,JMINUS,MONTH)
      DIMENSION
     *              ZM(08,14),CELL(08,14)
      COMMON        PHIS(08,14),FD(08,14),TOPOG(08,14),SINL(46),COSL(46)
      COMMON
     $              PC(8,14),TSC(8,14),SHSC(8,14),GTC(8,14),GWC(8,14),
     $              UC(8,14,3),VC(8,14,3),TC(8,14,3),SHC(8,14,3),PLK(10),
     $              SGC(8,14),US(08,14),VS(08,14)
      COMMON
     *          PLE(10), TLE(10), RH(10),TH(10),DSIG(10),SHL(10),
     *         SHLE(10),RE(10),SH(8,14,3)    ,PL(10),
     *         GT(08,14),SHS(08,14),TL(10),
     *          SLBEDO(08,14), TS(08,14), GW(08,14),ROK(08,14),
     *         IWR(10),SIGE(10),SIG(10)
      COMMON
     *              RHS,DTS,CD,EDV,ZLN,DRAW,PREVAP,PLANT,EVE,E6DT,
     *RHOS,CZH,DTRBFT,TERM1,TERM2,TERM3,TERM4,TERM5, DENOM,RADTRM,
     *              SNFAL,RAIN,OVER,WETR,WET,TAU,WMAG,ELE
      LOGICAL OCEAN,SNOW,ICE,LAND,MIXWI,FROST
      LOGICAL        UCLA,UCNI,UCNII,UCNJJA,ASSIM,TINPT
      LOGICAL PRIN,PRISMV,PRSURV,PRGRT,PRMCEV
      INTEGER PARM10,PARM11,PARM12,PARM13,PARM50,PARM51,PARM52,PARM53
      INTEGER*2 SLBEDO
C
C                             CMS: E SUB PRINT
C
C                             LOGICAL PRINT CONTROL VARIABLES
C
```

```
      PRIN=.TRUE.                                                       OLM10140
      PRISMV=.TRUE.                                                     OLM10150
      PRSURV=.TRUE.                                                     OLM10160
      PRGRT=.TRUE.                                                      OLM10170
      PRMCEV=.TRUE.                                                     OLM10180
C                                                                       OLM10190
C                                                                       OLM10200
C                            PRINT CONTROL VARIABLES                    OLM10210
C                                                                       OLM10220
      PARM10=I2C                                                        OLM10230
      PARM11=J2C                                                        OLM10240
      PARM12=IHH                                                        OLM10250
      PARM13=1                                                          OLM10260
      PARM50=I                                                          OLM10270
      PARM51=J                                                          OLM10280
      PARM52=IHH                                                        OLM10290
      PARM53=IPR                                                        OLM10300
C                                                                       OLM10310
C                            INITIALIZED VARIABLES                      OLM10320
C                                                                       OLM10330
      IF(IPR.NE.1.OR..NOT.PRIN) GO TO 305                               OLM10340
C                                                                       OLM10350
C                  INDEX FOR CELL                                       OLM10360
      T1=JMINUS-1.                                                      OLM10370
      DO 1217 J=1,JMAX                                                  OLM10380
      T1=T1+1                                                           OLM10390
      T2=(IMINUS-1)/100.                                                OLM10400
      DO 1217 I=1,IMAX                                                  OLM10410
      T2=T2+.01                                                         OLM10420
      CELL(J,I)=T1+T2                                                   OLM10430
 1217 CONTINUE                                                          OLM10440
C                                                                       OLM10450
      WRITE(6,234)                                                      OLM10460
  234 FORMAT(  //,45X,'GISS INDEX FOR CELL (J.I)')                      OLM10470
      WRITE(6,90)  (I,I=1,IMAX)                                         OLM10480
      J=JMAX+1                                                          OLM10490
      DO 1216 JJ=1,JMAX                                                 OLM10500
      J=J-1                                                             OLM10510
      WRITE(6,233) J,(CELL(J,I),I=1,IMAX)                               OLM10520
```

```
 1216 CONTINUE                                                          OLM10530
C                                                                       OLM10540
      WRITE(6,201)                                                      OLM10550
  201 FORMAT(5X,//,38X,'SURFACE ALBEDO FOR JULY, DSNAME = I527ALBD')    OLM10560
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM10570
      J=JMAX+1                                                          OLM10580
      DO 1203 JJ=1,JMAX                                                 OLM10590
      J=J-1                                                             OLM10600
      WRITE(6,203)   J,(SLBEDO(J,I),I=1,IMAX)                           OLM10610
 1203 CONTINUE                                                          OLM10620
  203 FORMAT(  08(2X,I3,14(4X,I2,2X)  ))                                OLM10630
C                                                                       OLM10640
      WRITE(6,207)                                                      OLM10650
  207 FORMAT(  //,40X,'SURFACE ELEVATION(GEOPOTENTIAL HT)  ')           OLM10660
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM10670
      J=JMAX+1                                                          OLM10680
      DO 1204 JJ=1,JMAX                                                 OLM10690
      J=J-1                                                             OLM10700
      WRITE(6,218)   J,(PHIS(J,I),I=1, IMAX)                            OLM10710
 1204 CONTINUE                                                          OLM10720
C                                                                       OLM10730
      WRITE(6,209)  MONTH                                               OLM10740
  209 FORMAT(  //,44X,'TOPOG ARRAY FOR MONTH = ',I2)                    OLM10750
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM10760
      J=JMAX+1                                                          OLM10770
      DO 1206 JJ=1,JMAX                                                 OLM10780
      J=J-1                                                             OLM10790
      WRITE(6,210)   J,(TOPOG(J,I),I=1,IMAX)                            OLM10800
 1206 CONTINUE                                                          OLM10810
  210 FORMAT(      08(2X,I3,1X,14(F7.0,1X)  ))                          OLM10820
C                                                                       OLM10830
      WRITE(6,212)                                                      OLM10840
  212 FORMAT(  //,43X,'INITIAL SURFACE TEMPERATURE(K)')                 OLM10850
      WRITE(6,90)  (I,I=1,IMAX)                                         OLM10860
      J=JMAX+1                                                          OLM10870
      DO 1207 JJ=1,JMAX                                                 OLM10880
      J=J-1                                                             OLM10890
      WRITE(6,233)   J,(TSC(J,I),I=1,IMAX)                              OLM10900
 1207 CONTINUE                                                          OLM10910
```

```
C                                                                       OLM10920
      WRITE(6,214)                                                      OLM10930
  214 FORMAT(  //,43X,'INITIAL GROUND TEMPERATURE(K)')                  OLM10940
      WRITE(6,90)  (I,I=1,IMAX)                                         OLM10950
      J=JMAX+1                                                          OLM10960
      DO 1208 JJ=1,JMAX                                                 OLM10970
      J=J-1                                                             OLM10980
      WRITE(6,233)  J,(GTC(J,I),I=1,IMAX)                               OLM10990
 1208 CONTINUE                                                          OLM11000
C                                                                       OLM11010
      WRITE(6,216)                                                      OLM11020
  216 FORMAT(  //,43X,'INITIAL SURFACE PRESSURE(MB)')                   OLM11030
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM11040
      J=JMAX+1                                                          OLM11050
      DO 1209 JJ=1,JMAX                                                 OLM11060
      J=J-1                                                             OLM11070
      WRITE(6,218)  J,(PC(J,I),I=1,IMAX)                                OLM11080
 1209 CONTINUE                                                          OLM11090
  218 FORMAT(  8(2X,I3,1X,14(F7.1,1X)   ))                              OLM11100
C                                                                       OLM11110
      WRITE(6,205)                                                      OLM11120
  205 FORMAT(/,2X,38X,'INITIAL GROUND WETNESS MATRIX(GWC)')             OLM11130
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM11140
   90 FORMAT(/,3X,'J  I' ,14(I3,5X))                                    OLM11150
   91 FORMAT(/,3X,' J/I' ,14(I3,5X))                                    OLM11160
      J=JMAX+1                                                          OLM11170
      DO 1210 JJ=1,JMAX                                                 OLM11180
      J=J-1                                                             OLM11190
      WRITE(6,200)  J,(GWC(J,I),I=1,IMAX)                               OLM11200
 1210 CONTINUE                                                          OLM11210
  200 FORMAT(      08(2X,I3,14(F7.4,1X)   ))                            OLM11220
C                                                                       OLM11230
      WRITE(6,237)                                                      OLM11240
  237 FORMAT(//,45X,'SURFACE SPECIFICATION',/,10X,'1: OCEAN, ',3X,      OLM11250
     1'2: LOAMY SOIL, ',3X,'3:SANDY SOIL,',4X,'4:  ')                   OLM11260
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM11270
      J=JMAX+1                                                          OLM11280
      DO 1222 JJ=1,JMAX                                                 OLM11290
      J=J-1                                                             OLM11300
```

```
      WRITE(6,233) J,(ROK(J,I),I=1,IMAX)                                OLM11310
 1222 CONTINUE                                                          OLM11320
C                                                                       OLM11330
      WRITE(6,236)                                                      OLM11340
  236 FORMAT(//, 34X,'TRANFORMED GROUND WETNESS MATRIX(GW, 0-.5 SCALE)')OLM11350
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM11360
      J=JMAX+1                                                          OLM11370
      DO 1220 JJ=1,JMAX                                                 OLM11380
      J=J-1                                                             OLM11390
      WRITE(6,200) J,(GW(J,I),I=1,IMAX)                                 OLM11400
 1220 CONTINUE                                                          OLM11410
C                                                                       OLM11420
      WRITE(6,235)                                                      OLM11430
  235 FORMAT(//,45X,'WMAG COMPONENT : FD(J,I)')                         OLM11440
      WRITE(6,90)  (I,I=1,IMAX)                                         OLM11450
      J=JMAX+1                                                          OLM11460
      DO 1221 JJ=1,JMAX                                                 OLM11470
      J=J-1                                                             OLM11480
      WRITE(6,233) J,(FD(J,I),I=1,IMAX)                                 OLM11490
 1221 CONTINUE                                                          OLM11500
C                                                                       OLM11510
      IF(IHH.EQ.1)  WRITE(6,240)                                        OLM11520
      IF(IHH.GT.1)  WRITE(6,221)                                        OLM11530
  240 FORMAT(//,45X,'SURFACE SPECIFIC HUMIDITY')                        OLM11540
  221 FORMAT(  //,47X,'NET RADIATION(LY/DAY)')                          OLM11550
      WRITE(6,91)  (I,I=1,IMAX)                                         OLM11560
      J=JMAX+1                                                          OLM11570
      DO 1211 JJ=1,JMAX                                                 OLM11580
      J=J-1                                                             OLM11590
      IF(IHH.EQ.1)    WRITE(6,223)   J,(SHSC(J,I),I=1,IMAX)             OLM11600
      IF(IHH.GT.1)    WRITE(6,218)   J,(SHSC(J,I),I=1,IMAX)             OLM11610
 1211 CONTINUE                                                          OLM11620
      LL=0                                                              OLM11630
      DO 229 L=1,3                                                      OLM11640
      LL=L+6                                                            OLM11650
C                                                                       OLM11660
      WRITE(6,222) LL                                                   OLM11670
  222 FORMAT(  //,45X,'X COMP OF VEL AT LEVEL',I2)                      OLM11680
      WRITE(6,90)  (I,I=1,IMAX)                                         OLM11690
```

```
      J=JMAX+1
      DO 1212 JJ=1,JMAX
      J=J-1
      WRITE(6,233)      J,(UC(J,I,L),I=1,IMAX)
 1212 CONTINUE
  233 FORMAT(           08(1X,I3,1X,  14(F7.2,1X)   ))
C
      WRITE(6,224) LL
  224 FORMAT(  //,45X,'Y COMP OF VEL AT LEVEL' , I2)
      WRITE(6,90)  (I,I=1,IMAX)
      J=JMAX+1
      DO 1213 JJ=1,JMAX
      J=J-1
      WRITE(6,233)      J,(VC(J,I,L),I=1,IMAX)
 1213 CONTINUE
C
      WRITE(6,225)  LL
  225 FORMAT(  //,43X,'TEMPERATURE OF AIR AT LEVEL',I2)
      WRITE(6,90)  (I,I=1,IMAX)
      J=JMAX+1
      DO 1214 JJ=1,JMAX
      J=J-1
      WRITE(6,233)      J,(TC(J,I,L),I=1,IMAX)
 1214 CONTINUE
C
      WRITE(6,226)  LL
  226 FORMAT(  //,45X,'SPEC HUMIDITY AT LEVEL', I2)
      WRITE(6,90)  (I,I=1,IMAX)
      J=JMAX+1
      DO 1215 JJ=1,JMAX
      J=J-1
      WRITE(6,223)      J,(SHC(J,I,L),I=1,IMAX)
 1215 CONTINUE
  223 FORMAT(           08(1X,I3,1X,  14(F7.4,1X)   ))
  229 CONTINUE
C
  305 CONTINUE
C
C                              SURFACE VARIABLES
```

```
C                                                                       OLM12090
      IF(IPR.NE.2.OR..NOT.PRISMV) GO TO 395                             OLM12100
  396 PARM13=2                                                          OLM12110
      IF(PARM10.EQ.PARM50.AND.PARM11.EQ.PARM51.AND.PARM12.EQ.PARM52     OLM12120
     *.AND.PARM13.EQ.PARM53)                                            OLM12130
     *GO TO 320                                                         OLM12140
      GO TO 395                                                         OLM12150
  320 CONTINUE                                                          OLM12160
      WRITE(6,490)                                                      OLM12170
  490 FORMAT(/,04X, 'RHS', 07X, 'DTS',07X, 'ELE',08X, 'EDV',07X, 'ZLN', OLM12180
     *05X,'SHLE(10)',03X, 'SHL(9)', 04X, 'DRAW',05X,'TLE(10)')          OLM12190
      WRITE(6,500) RHS,DTS,ELE,EDV,ZLN,SHLE(10),SHL(9),DRAW,TLE(10)     OLM12200
  500 FORMAT(2X,09(F8.4,2X))                                            OLM12210
  395 CONTINUE                                                          OLM12220
C                                                                       OLM12230
C                              GROUND TERMPERATURE CALCULATION VARIABLES OLM12240
C                                                                       OLM12250
      IF(IPR.NE.4.OR..NOT.PRGRT) GO TO 605                              OLM12260
  604 PARM13=4                                                          OLM12270
      IF(PARM10.EQ.PARM50.AND.PARM11.EQ.PARM51.AND.PARM12.EQ.PARM52     OLM12280
     *.AND.PARM13.EQ.PARM53)                                            OLM12290
     *GO TO 510                                                         OLM12300
      GO TO 605                                                         OLM12310
  510 CONTINUE                                                          OLM12320
      WRITE(6,595)                                                      OLM12330
  595 FORMAT(6X, 'RHOS',07X, 'DTS ',08X,'CZH',              07X,        OLM12340
     *'WMAG ',06X, 'TERM2', 05X,'TERM3', 06X,  'TERM4',06X,'TL(9)'      OLM12350
     *,06X,'DENOM',06X,'RADTRM',06X, 'GT ')                             OLM12360
      WRITE(6,600) RHOS,DTS ,CZH,       WMAG ,TERM2,TERM3,TERM4,        OLM12370
     *TL(9),DENOM,RADTRM,GT(J,I)                                        OLM12380
  600 FORMAT(1X,11(F10.3,1X))                                           OLM12390
  605 CONTINUE                                                          OLM12400
C                                                                       OLM12410
C                              MOISTURE CONTINUITY EQ. VARIABLES        OLM12420
C                                                                       OLM12430
      IF(IPR.NE.5.OR..NOT.PRMCEV) GO TO 695                             OLM12440
  696 PARM13=5                                                          OLM12450
      IF(PARM10.EQ.PARM50.AND.PARM11.EQ.PARM51.AND.PARM12.EQ.PARM52     OLM12460
     *.AND.PARM13.EQ.PARM53)                                            OLM12470
```

```
     *GO TO 610                                                         OLM12480
      GO TO 695                                                         OLM12490
  610 CONTINUE                                                          OLM12500
      WRITE(6,690)                                                      OLM12510
  690 FORMAT(5X,'SNFAL', 05X,'RAIN',06X, 'OVER',06X,'PLANT',            OLM12520
     *04X,'POT-E',04X,'ACTUAL-E',04X,      'WETR',06X, 'WET',           OLM12530
     *7X, 'RH(9)',6X,'PL(9)', 6X,'SHL(9)')                              OLM12540
      WRITE(6,700) SNFAL,RAIN,OVEP,PLANT,PREVAP,E6DT,WETR,WET,          OLM12550
     *RH(9),PL(9),SHL(9)                                                OLM12560
  700 FORMAT(2X,11(F9.4,1X),//)                                         OLM12570
  695 CONTINUE                                                          OLM12580
C        //EXEC     LDR                                                 OLM12590
C         /DD   008 DSNAME=DJJA                                         OLM12600
C        /EXEC     *                                                    OLM12610
C                                                                       OLM12620
      I=PARM50                                                          OLM12630
      J=PARM51                                                          OLM12640
C                                                                       OLM12650
      RETURN                                                            OLM12660
      END                                                               OLM12670
```