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**SNOWMELT FORECASTING -  
FURTHER COLD REGIONS DEVELOPMENT OF  
OPERATIONAL HYDROLOGICAL FORECASTING**

Volume 2

by

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March 1994

European Research Office

U.S. Corps of Engineers

London            England

CONTRACT NUMBER DAJA45-89-C-0028

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DTIC QUALITY INSPECTED 5

Approved for Public Release : Distribution Unlimited

DTIC  
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VOLUME 2

9498 94-11249



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**PREFACE**

This volume contains all the information that is required to operate the computer simulation model SNOMO. The input files required, the operational logic of SNOMO and the output produced by SNOMO are discussed in detail. A full listing of the SNOMO Fortran-77 code is included.

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## CHAPTER 1: INPUT

### 1.1 Cell division.

The catchment is subdivided into computational units, called cells. The factors used for this subdivision are slope angle, aspect, elevation and vegetation cover type. The method for catchment subdivision is described in detail in chapter 5 (volume 1) and need not be repeated here. The catchment to be modelled will therefore consist of, after subdivision, a number of cells each with an aspect, slope angle, elevation and vegetation cover value. The location of each cell in the catchment is also known. The depth and occurrence of snowcover is calculated for each cell and the results for all the cells are examined together in order to calculate the snowcover depth and distribution over the whole catchment.

### 1.2 Input files.

The snowcover calculations are conducted separately for each cell. The presence of five data files (*snomo.dat*, *conif.dat*, *decid.dat*, *mix.dat* and *lapse.dat*) is required in order for SNOMO to operate correctly. The input required for these 5 files will be considered in detail below and has also been discussed in chapter 4 (volume 1).

#### 1.2.1 *snomo.dat*.

Tables 1.1, 1.2 and 1.3 show sample *snomo.dat* files for cells 1 and 24 in 1988 and cell 1 in 1989 for the W3 catchment, Sleepers River Research Watershed, Danville, Vermont. Table 1.4 shows the variables contained in *snomo.dat*. The variables are considered in detail below in the order that they appear in the data file.

Table 1.1. Sample *snomo.dat* file for cell 1, W3, 1988.

```

1  1 1988
2  0.0 0.06 0.03 0.99 0.95 0.136
3  0.0 0.24 0.08 0.94 0.40 0.410
4  0.0 0.36 0.09 0.92 0.39 1.600
5  1010 5 100
6  6.15 -92.83 64 44.47
7  1
8  3
9  69.0
10 5.0
11 100.0 0.0 -1.0
12 39
13 64 1100 -11.1 -2.8 71.00 0.5 0.7 0.0
14 65 1100 -16.3 -5.8 36.00 0.5 4.2 0.2
15 66 1100 -16.6 0.0 31.00 0.5 1.7 0.0
16 67 1100 -6.0 5.6 46.00 0.7 2.5 1.5
17 68 1100 -14.0 4.4 32.00 0.0 1.7 0.1
18 69 1100 -1.9 4.6 55.00 1.0 1.8 6.1
19 70 1100 -7.8 2.4 75.00 0.5 3.1 1.6
20 71 1100 -15.3 -7.8 42.00 0.0 3.4 1.0
21 72 1100 -16.9 -1.6 37.00 0.5 2.0 0.0
22 73 1100 -3.8 3.6 80.00 0.5 1.1 4.8
23 74 1100 -5.9 0.3 77.00 1.0 1.9 1.4
24 75 1100 -6.2 -2.1 73.00 0.5 2.2 1.2
25 76 1100 -6.5 0.0 68.00 0.7 1.9 2.0
26 77 1100 -10.9 2.7 36.00 0.5 2.5 0.1
27 78 1100 -9.7 2.8 43.00 1.0 1.2 0.0
28 79 1100 -15.3 0.3 46.00 0.5 2.8 0.5
29 80 1100 -19.0 -6.1 67.00 0.5 2.5 2.8
30 81 1100 -22.7 -14.9 51.00 0.4 3.6 0.5
31 82 1100 -19.1 -4.2 46.00 0.5 2.8 0.0
32 83 1100 -15.4 4.8 32.00 0.4 2.7 0.0
33 84 1100 -0.3 11.0 65.00 0.5 1.2 0.0
34 85 1100 -0.4 7.2 61.00 0.5 1.4 0.0
35 86 1100 4.4 7.9 92.00 0.5 0.8 20.7
36 87 1100 -2.2 4.8 92.00 0.5 3.5 10.7
37 88 1100 -6.1 -0.2 78.00 0.5 2.1 1.2
38 89 1100 -8.0 12.7 43.00 0.5 1.1 0.0
39 90 1100 1.8 13.5 31.00 0.0 2.1 0.0
40 91 1100 0.3 10.8 60.00 0.0 2.1 0.0
41 92 1100 0.3 11.0 38.00 0.3 2.2 0.0
42 93 1100 1.1 16.8 47.00 0.5 1.4 0.0
43 94 1100 4.5 6.5 88.00 0.5 1.4 0.2
44 95 1100 3.3 11.8 95.00 1.0 0.5 0.4
45 96 1100 3.3 9.4 95.00 1.0 1.4 16.3
46 97 1100 0.9 15.3 74.00 0.6 1.0 0.0

```

continued overleaf...

```

47 98 1100 0.3 12.9 61.00 0.5 1.0 0.0
48 99 1100 3.4 6.8 87.00 1.0 1.1 0.5
49 100 1100 1.0 8.7 45.00 0.5 2.9 0.5
50 101 1100 -0.3 6.7 82.00 0.0 3.2 0.0
51 102 1100 -0.7 8.0 76.00 0.5 1.8 1.2
52 103 1100 -0.5 12.5 53.00 0.5 1.2 0.0

```

Interpretation of *snomo.dat* file:

LINE 1 cell identification number, simulation year.

LINE 2 0.0, thermal diffusivity ( $\text{cm}^2 \text{min}^{-1}$ ), heat conductivity ( $\text{cal cm}^{-2} \text{min}^{-1} \text{K}^{-1}$ ), emissivity (decimal), albedo (decimal), density ( $\text{gm}^{-3}$ ): for new snow.

LINE 3 as line 2, but for old snow.

LINE 4 as line 2 and 3, but for sandy soil.

LINE 5 air pressure (mb), cloud type, instrument height (cm).

LINE 6 slope angle, aspect, start date, latitude.

LINE 7 lapse rate indicator.

LINE 8 vegetation cover type indicator.

LINE 9 initial snowdepth, (cm).

LINE 10 critical snowdepth (5cm).

LINE 11 depth of soil profile (cm), soil temperature at depth ( $^{\circ}\text{C}$ ), surface soil temperature ( $^{\circ}\text{C}$ ).

LINE 12 number of days in data file minus one.

LINES 13 daily meteorological data: Julian date, observation time, minimum air temperature ( $^{\circ}\text{C}$ ), maximum air temperature ( $^{\circ}\text{C}$ ),

TO 52 relative humidity (%), cloud cover (0-1), wind speed ( $\text{ms}^{-2}$ ).

Table 1.2. Sample *snomo.dat* file for cell 24, W3, 1988.

```
1 24 1988
2 0.0 0.06 0.03 0.99 0.95 0.136
3 0.0 0.24 0.08 0.94 0.40 0.410
4 0.0 0.36 0.09 0.92 0.39 1.600
5 1010 5 100
6 6.27 -101.37 64 44.47
7 0
8 0
9 69.0
10 5.0
11 100.0 0.0 -1.0
12 39
13 64 1100 -11.1 -2.8 71.00 0.5 0.7 0.0
Lines 14 to 52 as file (1).
```

Table 1.3. Sample *snomo.dat* file for cell 1, W3, 1989.

```

1 1 1989
2 0.0 0.06 0.03 0.99 0.95 0.136
3 0.0 0.24 0.08 0.94 0.40 0.410
4 0.0 0.36 0.09 0.92 0.39 1.600
5 1010 5 100
6 6.15 -92.83 64 44.47
7 1
8 3
9 52.9
10 5.0
11 100.0 0.0 -1.0
12 46
13 64 1100 -8.5 0.7 96.00 0.5 0.3 7.1
14 65 1100 -19.9 -9.4 81.00 1.0 2.5 0.0
15 66 1100 -28.7 -15.8 65.00 0.5 1.7 0.0
16 67 1100 -20.4 -5.9 72.00 0.0 1.3 0.0
17 68 1100 -14.9 -1.2 67.00 0.0 1.4 0.0
18 69 1100 -11.5 1.8 52.00 0.5 1.7 0.0
19 70 1100 -7.6 2.02 47.00 0.5 1.9 1.02
20 71 1100 -12.8 -1.7 87.00 0.5 2.4 1.8
21 72 1100 -16.0 -1.3 40.00 0.0 1.2 0.0
22 73 1100 -3.9 8.6 61.00 0.5 1.0 0.0
23 74 1100 3.4 14.3 96.00 0.5 1.8 0.0
24 75 1100 -4.6 2.5 78.00 0.5 2.2 0.0
25 76 1100 -6.7 2.6 75.00 1.0 2.1 3.1
26 77 1100 -8.1 1.0 97.00 0.5 0.4 17.0
27 78 1100 -12.5 -6.1 84.00 0.5 1.7 1.02
28 79 1100 -12.1 -0.6 87.00 1.0 1.2 1.52
29 80 1100 -9.3 -0.9 94.00 0.5 2.0 7.6
30 81 1100 -14.3 -3.8 57.00 0.5 1.8 0.0
31 82 1100 -10.7 2.6 47.00 0.0 1.8 0.0
32 83 1100 -9.4 2.2 55.00 0.5 1.8 2.5
33 84 1100 -2.7 6.3 89.00 0.5 0.8 3.1
34 85 1100 0.0 6.5 91.00 0.5 1.1 0.0
35 86 1100 0.0 16.9 60.00 0.5 0.9 0.0
36 87 1100 7.0 17.1 79.00 0.2 0.8 2.3
37 88 1100 -0.2 13.8 65.00 1.0 1.7 13.5
38 89 1100 -2.4 0.4 93.00 0.5 1.2 18.3
39 90 1100 -2.7 0.3 97.00 1.0 0.6 10.2
40 91 1100 -2.3 0.2 94.00 0.5 1.9 4.3
41 92 1100 -3.4 6.5 83.00 0.5 1.3 0.0
42 93 1100 1.0 3.8 94.00 1.0 1.1 26.2
43 94 1100 1.2 4.6 99.00 1.0 0.8 6.9
44 95 1100 4.3 14.0 90.00 0.4 0.9 8.4
45 96 1100 0.1 6.5 98.00 0.5 1.9 21.3
46 97 1100 0.1 4.2 94.00 0.6 1.7 9.4

```

continued overleaf...



47	98	1100	-3.4	2.6	82.00	0.5	2.4	0.0
48	99	1100	-4.9	6.2	43.00	0.5	1.3	3.1
49	100	1100	-5.7	1.2	70.00	0.5	1.6	6.6
50	101	1100	-7.9	-0.2	70.00	0.7	1.7	0.0
51	102	1100	-7.1	4.2	66.00	0.5	0.7	0.0
52	103	1100	-1.1	5.9	58.00	0.5	1.9	0.0
53	104	1100	-0.3	5.2	73.00	0.9	1.1	0.0
54	105	1100	0.4	6.8	71.00	0.5	2.1	6.4
55	106	1100	1.0	4.6	97.00	0.5	0.9	4.6
56	107	1100	3.5	14.7	80.00	0.5	0.8	0.0
57	108	1100	0.4	11.1	95.00	0.5	2.4	3.8
58	109	1100	-0.9	5.9	53.00	0.5	1.9	0.0
59	110	1100	-0.6	5.2	90.00	0.5	2.1	1.8

Table 1.4. Description of variables in *snomo.dat*.

LINE	VARIABLE	REAL/ INTEGER	DESCRIPTION
1	CELL	I	Number of cell.
	YEAR	I	Year of simulation
2	VNEWSN(1,1)	R	New snow vector, 0.0.
	VNEWSN(1,2)	R	" " " , thermal diffusivity ( $\text{cm}^2 \text{min}^{-1}$ ).
	VNEWSN(1,3)	R	" " " , heat conductivity ( $\text{calcm}^{-2} \text{min}^{-1} \text{K}^{-1}$ ).
	VNEWSN(1,4)	R	" " " , emissivity (decimal).
	VNEWSN(1,5)	R	" " " , albedo (decimal).
	VNEWSN(1,6)	R	" " " , density ( $\text{gcm}^{-3}$ ).
3	VOLDSN(1,1)	R	Old snow vector, 0.0.
	VOLDSN(1,2)	R	" " " , thermal diffusivity ( $\text{cm}^2 \text{min}^{-1}$ ).
	VOLDSN(1,3)	R	" " " , heat conductivity ( $\text{calcm}^{-2} \text{min}^{-1} \text{K}^{-1}$ ).
	VOLDSN(1,4)	R	" " " , emissivity (decimal).
	VOLDSN(1,5)	R	" " " , albedo (decimal).
	VOLDSN(1,6)	R	" " " , density ( $\text{gcm}^{-3}$ ).
4	VSOIL(1,1)	R	Soil vector, 0.0.
	VSOIL(1,2)	R	" " , thermal diffusivity ( $\text{cm}^2 \text{min}^{-1}$ ).
	VSOIL(1,3)	R	" " , heat conductivity ( $\text{calcm}^{-2} \text{min}^{-1} \text{K}^{-1}$ ).
	VSOIL(1,4)	R	" " , emissivity (decimal).
	VSOIL(1,5)	R	" " , albedo (decimal).
	VSOIL(1,6)	R	" " , density ( $\text{gcm}^{-3}$ ).
5	PRESS	I	Air pressure (mb).
	NCLOUD	I	Cloud type, see table 1.2.
	ZA	I	Instrument height (cm).
6	SLOPE1	R	Cell slope angle (°)
	SURFC1	R	Cell aspect (°)
	DAY1	I	Start date (Julian calendar).
	LAT	R	Latitude of catchment (°).
7	ILAPSE	I	Lapse rate indicator. ILAPSE=0, elevation band 1500-2000ft. ILAPSE=1, elevation band 1000-1500ft.
8	IVEG	I	Cell vegetation cover type indicator. IVEG=1, coniferous cover. IVEG=2, deciduous cover. IVEG=3, mixed cover. IVEG=0, pasture and clear-cut (open).

continued overleaf...

9	SNDF1	R	Initial snowdepth (cm).
10	CRIC	R	Critical snowdepth (5cm).
11	SOILD	R	Depth of soil profile (cm).
	SOILT	R	Soil temperature at depth (°C).
	SSOLT	R	Surface soil temperature (°C).
12	N	I	Number of days to be modelled. Number of daily meteorological data days minus 1.
13			Daily meteorological data.
	XXX(1,8)	I	Date (Julian calender).
	XXX(1,1)	I	Observation time (24hr clock).
	YYY(1,1)	R	Minimum daily air temperature (°C).
	YYY(1,9)	R	Maximum daily air temperature (°C).
	YYY(1,2)	R	Relative humidity (%).
	YYY(1,3)	I	Cloud cover (0-1).
	YYY(1,6)	R	Wind speed (ms <sup>-1</sup> ).
	YYY(1,7)	R	Precipitation (mm water).

LINE 1

## 1. CELL

The number of the cell. Each cell is numbered for easy identification.

## 2. YEAR

The year of the simulation.

LINE 2: 'New' snow vector.

The vector for the physical characteristics of 'new' snow. Chapter 4 (volume 1) considered the division of the physical characteristics of snow into those commonly associated with 'new' (fresh) snow and 'old' snow. Values are taken from various sources or measurements on site if available. The physical characteristics required are thermal diffusivity ( $\text{cm}^2\text{min}^{-1}$ ), heat conductivity ( $\text{calcm}^{-2}\text{min}^{-1}\cdot\text{K}^{-1}$ ), emissivity (decimal), albedo (decimal) and density ( $\text{gcm}^{-3}$ ). The first value in the vector is always input as zero. This is because it represents snowpack depth and is calculated within the program.

LINE 3: 'Old' snow vector.

As line 2, except concerned with the values of the physical characteristics of 'old' snow.

LINE 4: Soil vector.

As lines 2 and 3, except concerned with the values of the physical characteristics of the soil. Soil type is taken as the predominant soil type for that particular cell or catchment. The soil vector is rarely used and therefore the accuracy of the soil values is not particularly important. Again values can be taken from the literature, or on site.

LINE 5

## 1. PRESS.

Air pressure (mb). The average air pressure for the simulation period is used, or a median value.

## 2. NLOUD.

Values for cloud cover type are contained in table 1.5. The average cloud cover type is used or, in the absence of sufficient data, a default cloud cover type of 5 (stratocumulus) is used.

## 3. ZA.

Instrument height is the average height (cm) of the instruments used to measure the meteorological data, ie. wind speed and relative humidity, from the ground/snow surface. If this measurement is unavailable or is too variable a default value of 100cm is used.

LINE 6

## 1. SLOPE1.

Cell slope angle (°).

## 2. SURFC1.

Cell aspect. The cell aspect is measured in degrees from South with westerly values positive and easterly values negative, ie. West=+90° and East=-90°.

## 3. DAY1.

Date of start of simulation, Julian calender.

## 4. LAT.

Latitude of catchment or cell (degrees and minutes). The latitude of the midpoint or mouth of the catchment can be used, at the operator's discretion.

LINE 7

## 1. ILAPSE.

Lapse rate indicator. SNOMO is currently set up for the W3 catchment, Sleepers River Research Watershed, Danville, Vermont. When subdivided the elevations derived for each cell ranged within 1000-2000ft a.s.l.. A midpoint of 1500ft a.s.l. was used as a

Table 1.5. Cloud Genera and Cloud Type Indices\*, Balick et.al. (1981a).

Cloud Genera	Abbreviation	Index value	Comments
Cirrus	Ci	1	High clouds composed of white delicate filaments, patches of narrow bands, elements often curved or slanted and smaller than Cs, never overcast or precipitating.
Cirrostratus	Cs	2	High clouds appearing as whitish veil usually fibrous, often produces halo phenomena, thinner than As, does not appear to move, nonprecipitating.
Alto cumulus	Ac	3	Midlevel clouds, patches, usually broken, lee wave clouds, elements smaller than Sc, nonprecipitating.
Altostratus	As	4	Midlevel grey sheet or layer of striated, fibrous or uniform appearance, large horizontal extent; thicker than Cs, thinner than Ns, precipitation generally light and continuous (if any).
Stratocumulus	Sc	5	Grey and/or whitish layer or patch, nearly always has dark spots and is nonfibrous; elements larger than Ac, nonprecipitating.
Stratus	St	6	Grey rather uniform base, patches ragged if present, precipitation unusual but light and continuous if present, lower and more uniform than Sc, less dense and less 'wet' than Ns.
Nimbostratus	Ns	7	Grey often dark, diffuse, large horizontal and vertical extent, thicker than As, more uniform than Sc, often precipitating, precipitation continuous.
Fog	FG	8	

\* Cloud genera: Cumulus (Cu), Cirrocumulus (Cc) and Cumulonimbus (Cb) are not treated here. At low cloud covers (0.3) Cu and Cc may be approximated with Ac.

further subdivision of the elevation resulting in 2 elevation bands: 1000-1500ft and 1500-2000ft. If the elevation of the cell is between 1000-1500ft the lapse rate indicator is set to 1, if between 1500-2000 then it is set to 0. The elevation bands can be altered if required.

#### LINE 8

##### 1. IVEG.

Vegetation cover type indicator. Four vegetation cover types can be modelled using SNOMO:

IVEG-1, coniferous cover

IVEG-2, deciduous cover

IVEG-3, mixed cover

IVEG-0, pasture or clear-cut (open).

The vegetation cover types are those found at W3. Again, as with ILAPSE, these can be altered if necessary.

#### LINE 9

##### 1. SNDF1.

Initial snowdepth. This is the known (measured or estimated) snowdepth for the cell at the start of the simulation. If estimated the value for initial snowdepth is based on the relationship between snowdepth, vegetation cover type and elevation. If one value at a base station (1500-2000ft a.s.l) is available then:

(1) Cell with elevation < 1500ft a.s.l., -10cm.

(2) Cell with coniferous forest cover, -5cm.

(3) Cell with mixed forest cover, +5cm.

(4) Cell with deciduous forest cover, +10cm.

These values can be used or compiled according to another catchment.

#### LINE 10

##### 1. CRITDP.

Critical depth (5cm). This is the depth below which, because of the difficulty of accurate measurement, no snow is said to be

present.

LINE 11

1. SOILD.P.

Depth of soil profile (cm). Default value is 100cm.

2. SOILTP.

Soil temperature at depth (°C). Default value is 0°C. SNOMO does not currently model the temperatures within the soil or the heat flux across the ground/snow interface ( $Q_g$ ) and therefore the accuracy of SOILTP is not vital.

3. SSOLTP.

Surface soil temperature (°C). Default value of -1°C is used. Again, for the same reasons as SOILTP, accuracy is not vital.

LINE 12

1. N

The number of days to be modelled in the simulation. This is calculated as the number of daily meteorological data available in *snomo.dat* minus one.

LINE 13 and onward : Daily meteorological data.

1. XXX(1,8)

Julian date.

2. XXX(1,1)

Observation time (24hr clock), default value of 1100hrs.

3. YYY(1,1)

Minimum air temperature (°C).

4. YYY(1,9)

Maximum air temperature (°C).

5. YYY(1,2)

Relative humidity (%).

6. YYY(1,3)

Cloud cover amount (decimal).

7. YYY(1,6)



Wind speed ( $\text{ms}^{-1}$ )

8. YYY(1,7)

Precipitation ( $\text{mm}$  water).

Table 1.6 is provided for the guidance of the compilation of a *snomo.dat* file.

### 1.2.2 *conif.dat*, *decid.dat* and *mix.dat*.

These three data files contain the information required if the vegetation cover options of coniferous, deciduous or mixed cover are used. The files contain values of the variables  $\sigma_f$ ,  $\chi$ ,  $\epsilon_f$ ,  $\alpha_f$  and  $z_f$ . Examples of the three data files used for the W3 simulation are shown in table 1.7. The variables contained in the files are considered in chapter 4 (volume 1) and below:

1.  $\sigma_f$ , foliage cover fraction (0-1).

This describes the density of the vegetation cover.  $\sigma_f=0$  represents no foliage and therefore no radiative shielding and  $\sigma_f=1$  represents complete radiative blocking. Table 1.4 shows various limiting values of  $\sigma_f$  taken from Geiger (1965) and Deardorff (1978) for various vegetation covers.

2.  $\chi$ , state of vegetation (1-1000).

$\chi$  is used as a multiplier of the stomatal resistance function. A summer value, when the vegetation is healthy and active, is 1, a winter and therefore dormant or dead vegetation cover value is 1000. Other values can be chosen to adjust stomatal resistance for moisture stress, senescence or other factors.

3.  $\epsilon_f$ , foliage emissivity (decimal).

4.  $\alpha_f$ , foliage albedo (decimal).

5.  $z_f$ , foliage height (cm).

Values for  $\epsilon_f$  and  $\alpha_f$  can be obtained from the literature.

Table 1.6. Compilation guideline for *snomo.dat*.

All input on the same line is separated by at least 1 space and starts in the first column.

## LINE 1

- |                       |       |
|-----------------------|-------|
| 1. Number of cell     | _____ |
| 2. Year of simulation | _____ |

## LINE 2

- |                                 |       |
|---------------------------------|-------|
| 1. 0.0                          | _____ |
| 2. New snow thermal diffusivity | _____ |
| 3. " " heat conductivity        | _____ |
| 4. " " emissivity               | _____ |
| 5. " " albedo                   | _____ |
| 6. " " density                  | _____ |

## LINE 3

- |                                 |       |
|---------------------------------|-------|
| 1. 0.0                          | _____ |
| 2. Old snow thermal diffusivity | _____ |
| 3. " " heat conductivity        | _____ |
| 4. " " emissivity               | _____ |
| 5. " " albedo                   | _____ |
| 6. " " density                  | _____ |

## LINE 4

- |                             |       |
|-----------------------------|-------|
| 1. 0.0                      | _____ |
| 2. Soil thermal diffusivity | _____ |
| 3. " heat conductivity      | _____ |
| 4. " emissivity             | _____ |
| 5. " albedo                 | _____ |
| 6. " density                | _____ |

continued overleaf...

## LINE 5

1. Air pressure \_\_\_\_\_
2. Cloud type \_\_\_\_\_
3. Instrument height \_\_\_\_\_

## LINE 6

1. Cell slope angle \_\_\_\_\_
2. Cell aspect \_\_\_\_\_
3. Start date \_\_\_\_\_
4. Latitude of catchment or cell \_\_\_\_\_

## LINE 7

1. Lapse rate indicator \_\_\_\_\_

## LINE 8

1. Cell vegetation cover type indicator \_\_\_\_\_

## LINE 9

1. Initial snowdepth \_\_\_\_\_

## LINE 10

1. Critical snowdepth \_\_\_\_\_

## LINE 11

1. Depth of soil profile \_\_\_\_\_
2. Soil temperature at depth \_\_\_\_\_
3. Surface soil temperature \_\_\_\_\_

## LINE 12

1. Number of days to be modelled \_\_\_\_\_

continued overleaf...

## LINE 13

1. Julian date \_\_\_\_\_
2. Observation time \_\_\_\_\_
3. Minimum daily air temperature \_\_\_\_\_
4. Maximum daily air temperature \_\_\_\_\_
5. Relative humidity \_\_\_\_\_
6. Cloud cover amount \_\_\_\_\_
7. Wind speed \_\_\_\_\_
6. Precipitation \_\_\_\_\_

Table 1.7. *conif.dat*, *decid.dat* and *mix.dat* files used for W3.

*conif.dat*:           0.70,1000,0.98,0.10,2000  
*decid.dat*:           0.50,1000,0.97,0.15,2000  
*mix.dat*:             0.60,1000,0.975,0.125,2000

Interpretation:

1.  $\sigma_f$ , foliage cover fraction (0-1)
2.  $\chi$ , state of vegetation (1-1000)
3.  $\epsilon_f$ , foliage emissivity (decimal)
4.  $\alpha_f$ , foliage albedo (decimal)
5.  $z_f$ , foliage height (cm).

Table 1.8. *lapse.dat* file used for W3.

*lapse.dat*:           2.0,1.0

Interpretation:

1. TMAX, lapse rate factor for daily maximum temperature ( $^{\circ}$ C).
2. TMIN, lapse rate factor for daily minimum temperature ( $^{\circ}$ C).

### 1.2.3 *lapse.dat*.

The file *lapse.dat* contains values for TMAX and TMIN. These are the lapse rate alteration of the maximum (TMAX) and minimum (TMIN) daily air temperatures. The values for the lapse rate alteration are those used for the catchment W3 and are obtained from the literature (chapters 4 and 6, volume 1). If applied to different catchments the values can be altered if necessary. An example of the *lapse.dat* file used for the W3 simulation is shown in table 1.8.

## CHAPTER 2: OUTPUT

### 2.1 Output file.

Table 2.1 shows the output file *SNOMO.RES* for cell 1, W3, 1988. The input file used was that shown in table 1.1. The output variables are considered below in the order in which they appear in *SNOMO.RES* and using the titles used in *SNOMO.RES*.

1. CELL NO.

The identification number of the cell.

2. YEAR

The year of the simulation.

3. JULIAN DATE

Date, Julian calender.

4. SNOWDEPTH

Calculated depth of snowpack (cm).

5. SNOWMELT

Calculated daily depth of snow melted, in both centimetres of snow and millimetres of water equivalent.

6. SNOWFALL

Daily snowfall (mm water equivalent). The value for snowfall on the first day of simulation is equal to the initial snowpack depth and is not related to the amount of daily snowfall.

7. DENSITY

Daily average snowpack density ( $\text{gcm}^{-3}$ ).

8. RAIN-ON-SNOW

Occurrence of a rain-on-snow event. 1-rain-on-snow event, 0-no rain-on-snow event.

Table 2.1. Sample SNOMO.RES file, for cell 1, W3, 1988

CELL NO.: 1  
YEAR: 1988

JULIAN	SNOWDEPTH	SNOWMELT		SNOWFALL	DENSITY	RAIN-ON-SNOW
DATE	(cm)	(cm snow)	(mm water)	(cm)	(G/M**3)	(1=yes, 0=no)
64.00	69.00	0.00	0.00	69.00	0.39	0
65.00	69.15	0.00	0.00	0.15	0.39	0
66.00	69.15	0.00	0.00	0.00	0.39	0
67.00	66.81	0.00	0.00	1.10	0.39	0
68.00	66.88	0.00	0.00	0.07	0.41	0
69.00	71.37	0.00	0.00	4.49	0.41	0
70.00	72.55	0.00	0.00	1.18	0.39	0
71.00	73.28	0.00	0.00	0.74	0.38	0
72.00	73.28	0.00	0.00	0.00	0.38	0
73.00	71.75	0.00	0.00	3.53	0.38	0
74.00	72.78	0.00	0.00	1.03	0.40	0
75.00	73.68	0.00	0.00	0.88	0.39	0
76.00	75.13	0.00	0.00	1.47	0.39	0
77.00	75.29	0.00	0.00	0.07	0.38	0
78.00	75.20	0.00	0.00	0.00	0.38	0
79.00	70.90	0.00	0.00	0.37	0.38	0
80.00	67.05	5.91	24.24	2.06	0.41	0
81.00	61.97	5.45	22.34	0.37	0.41	0
82.00	60.20	1.77	7.26	0.00	0.41	0
83.00	60.20	0.00	0.00	0.00	0.41	0
84.00	58.35	1.85	7.60	0.00	0.41	0
85.00	55.32	3.03	12.42	0.00	0.41	0
86.00	50.89	4.43	18.14	0.00	0.41	1
87.00	54.10	4.66	19.13	7.67	0.41	0
88.00	54.98	0.00	0.00	0.88	0.39	0
89.00	54.98	0.00	0.00	0.00	0.39	0
90.00	52.25	0.00	0.00	0.00	0.39	0
91.00	47.58	4.67	19.14	0.00	0.41	0
92.00	43.43	4.16	17.04	0.00	0.41	0
93.00	38.68	4.75	19.46	0.00	0.41	0
94.00	34.08	4.60	18.85	0.00	0.41	1
95.00	30.26	3.83	15.69	0.00	0.41	1
96.00	25.42	4.84	19.83	0.00	0.41	1
97.00	19.96	5.46	22.38	0.00	0.41	0
98.00	14.72	5.24	21.49	0.00	0.41	0
99.00	9.87	4.85	19.88	0.00	0.41	1
100.00	4.00	5.88	24.10	0.00	0.41	1



## CHAPTER 3: PROGRAMME DETAILS

### 3.1. Programme structure.

Chapter 4, volume 1, considers in detail the equations used by SNOMO to calculate snowdepth within one cell. This chapter presents the programme logic that enables these equations to be utilised and to interact successfully. Figure 3.1 shows the SNOMO programme logic. SNOMO broadly consists of 2 sections:

(1) Control programme.

This is responsible for the determination of the type of precipitation, the calculation of melt, the calculation of the affect of a rain-on-snow event, the calculation of the heat flux across the ground/snow interface ( $Q_g$ ), various operational markers, the calculation of the depth of the snowpack and the physical characteristics of the snowpack, the model input and the model output.

(2) Algorithm to calculate the majority of the components of the snowpack energy budget.

This algorithm is responsible for the calculation of the snowpack energy budget components  $K\downarrow$ ,  $K\uparrow$ ,  $L\downarrow$ ,  $L\uparrow$ ,  $Q_c$  and  $Q_e$  and the snowpack surface and internal temperatures. The algorithm is adapted from the US Corps of Engineers Terrain surface Temperature Model (TSTM) as developed by Balick *et.al.* (1981a & b). The basic equations used by the original TSTM remain the same as in the modified TSTM. TSTM has been heavily modified from its original state as presented in Balick *et.al.* (1981a & b) and has also been incorporated into the logic structure of SNOMO. The logic structure of TSTM is shown in figure 3.2. TSTM is operational for situations where a vegetation cover is present or absent. Vegetation cover is modelled using a vegetation cover algorithm, VEGIE, within TSTM.

The relationship between TSTM and VEGIE is shown in figure 3.3.

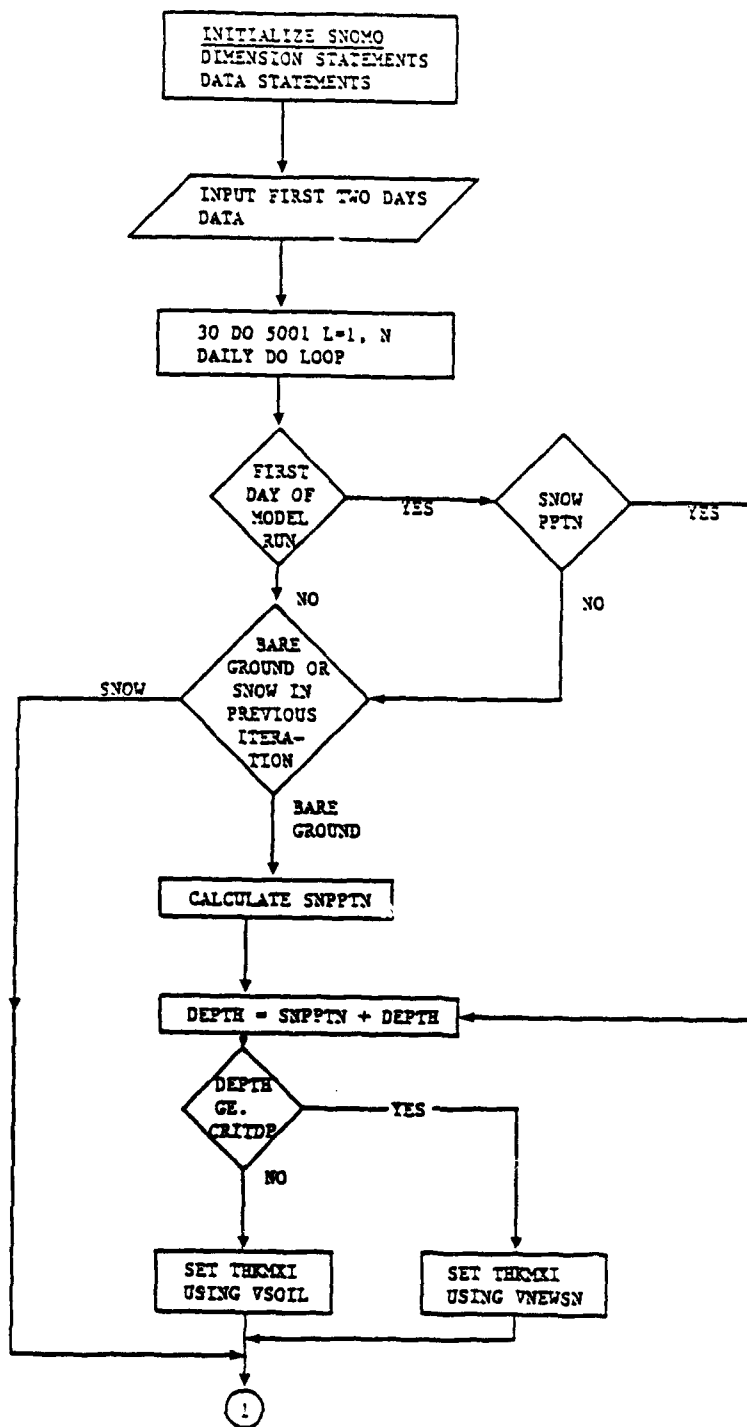


Figure 3.1. Simplified flowchart for SNOMO (sheet 1 of 4).

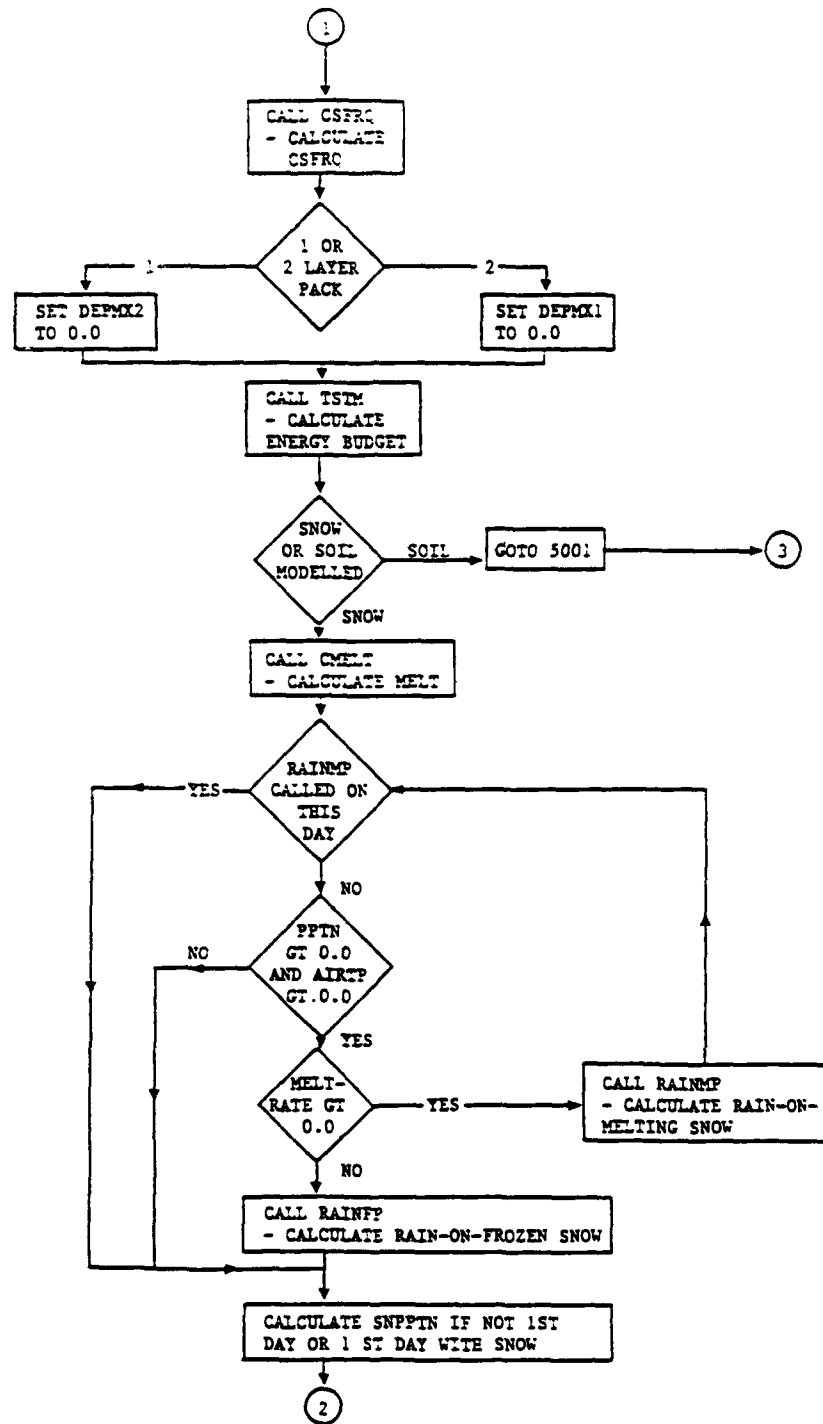


Figure 3.1. Simplified flowchart for SNOMO (sheet 2 of 4).

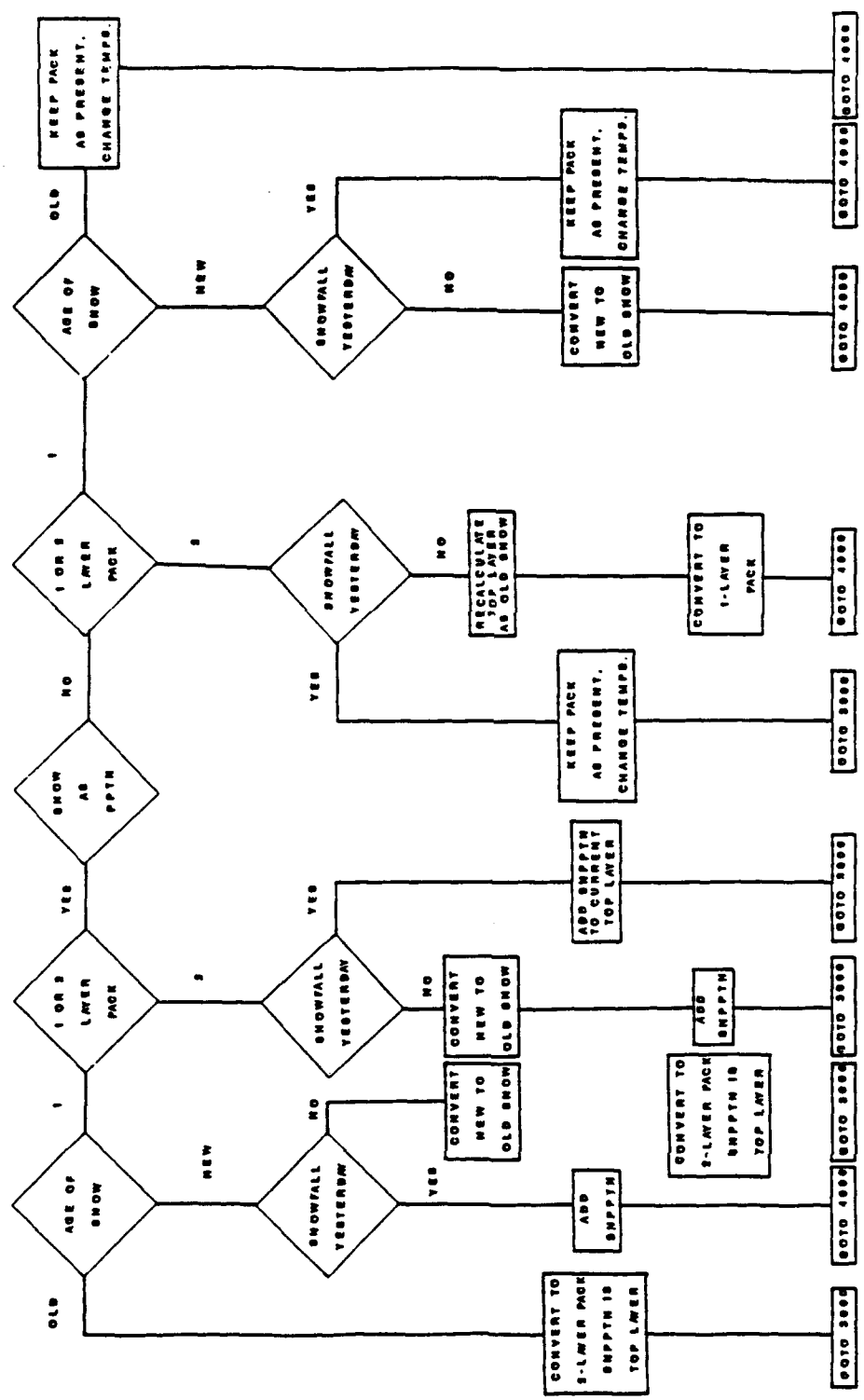


Figure 3.1. Simplified flowchart for SNOMO (sheet 3 of 4).

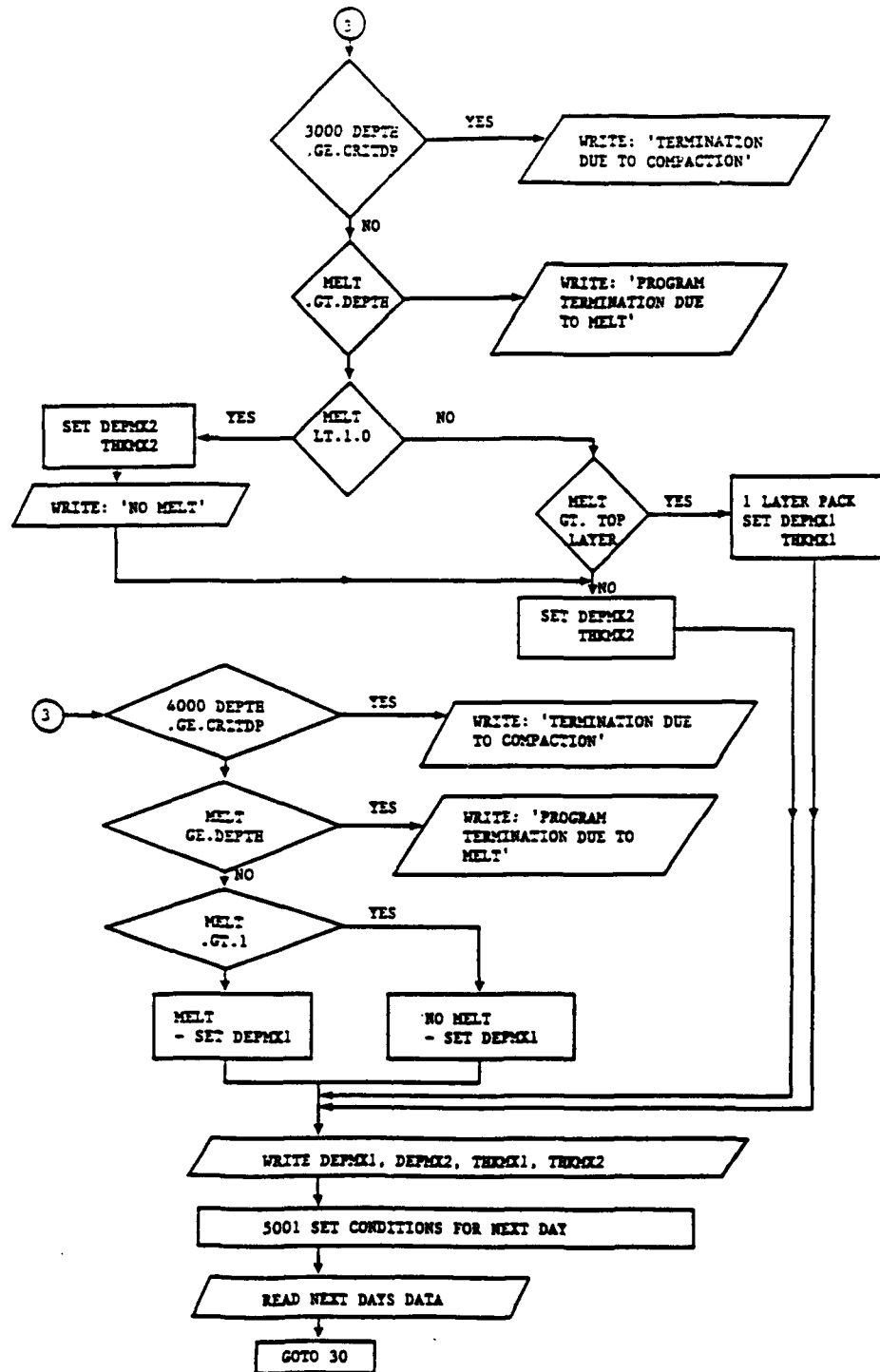


Figure 3.1. Simplified flowchart for SNOMO (sheet 4 of 4).

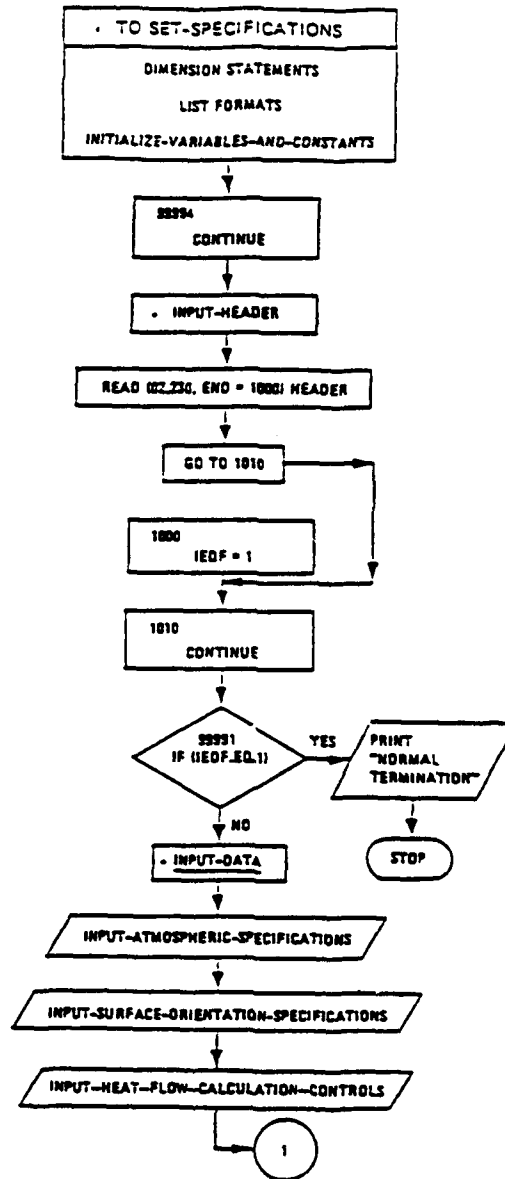


Figure 3.2. Simplified flowchart for TSTM, Balick *et al.*, 1981a (sheet 1 of 5).

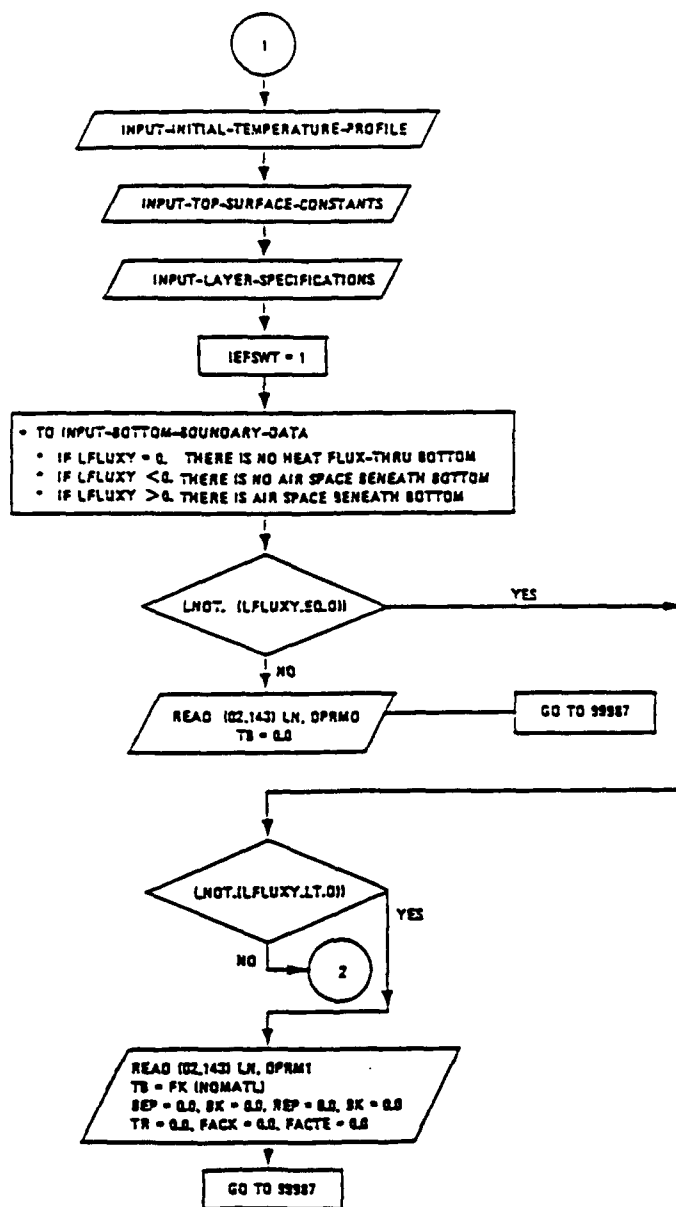


Figure 3.2. Simplified flowchart for TSTM, Balick *et al.*, 1981a (sheet 2 of 5).

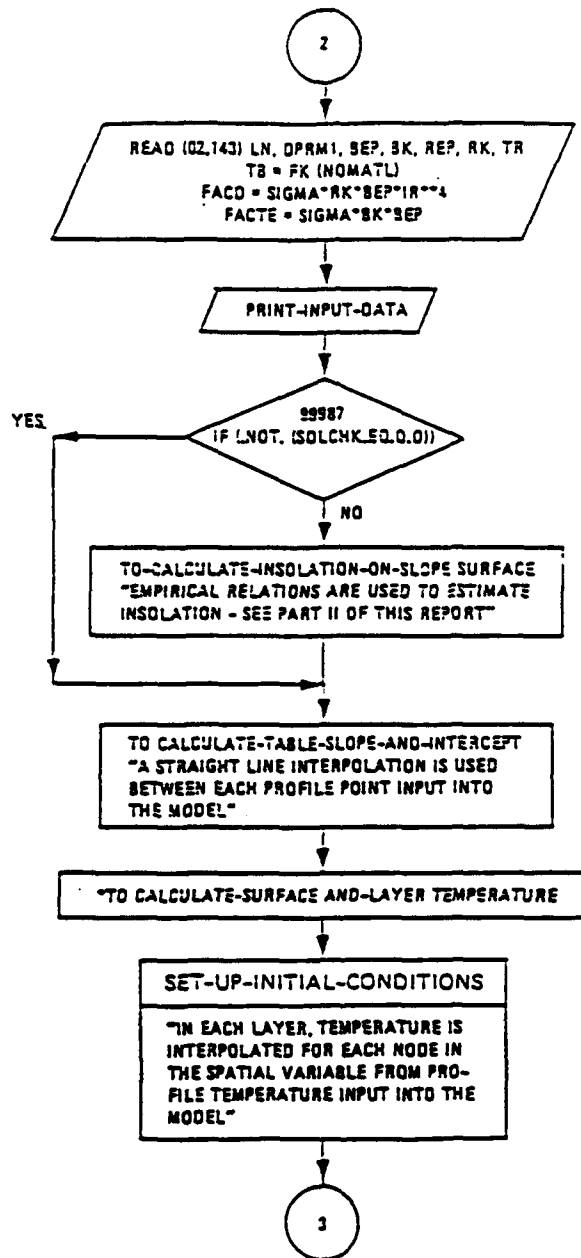


Figure 3.2. Simplified flowchart for TSTM, Balick *et al.*, 1981a (sheet 3 of 5).



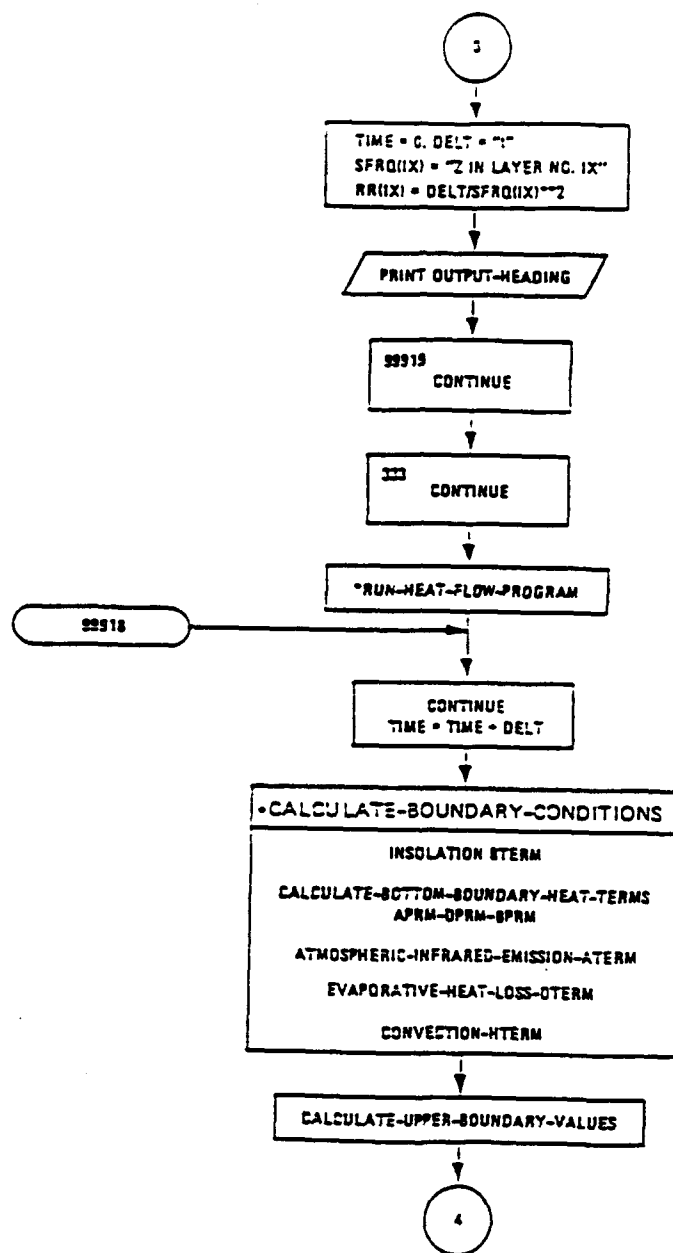


Figure 3.2. Simplified flowchart for TSM, Balick *et al.*, 1981a (sheet 4 of 5).

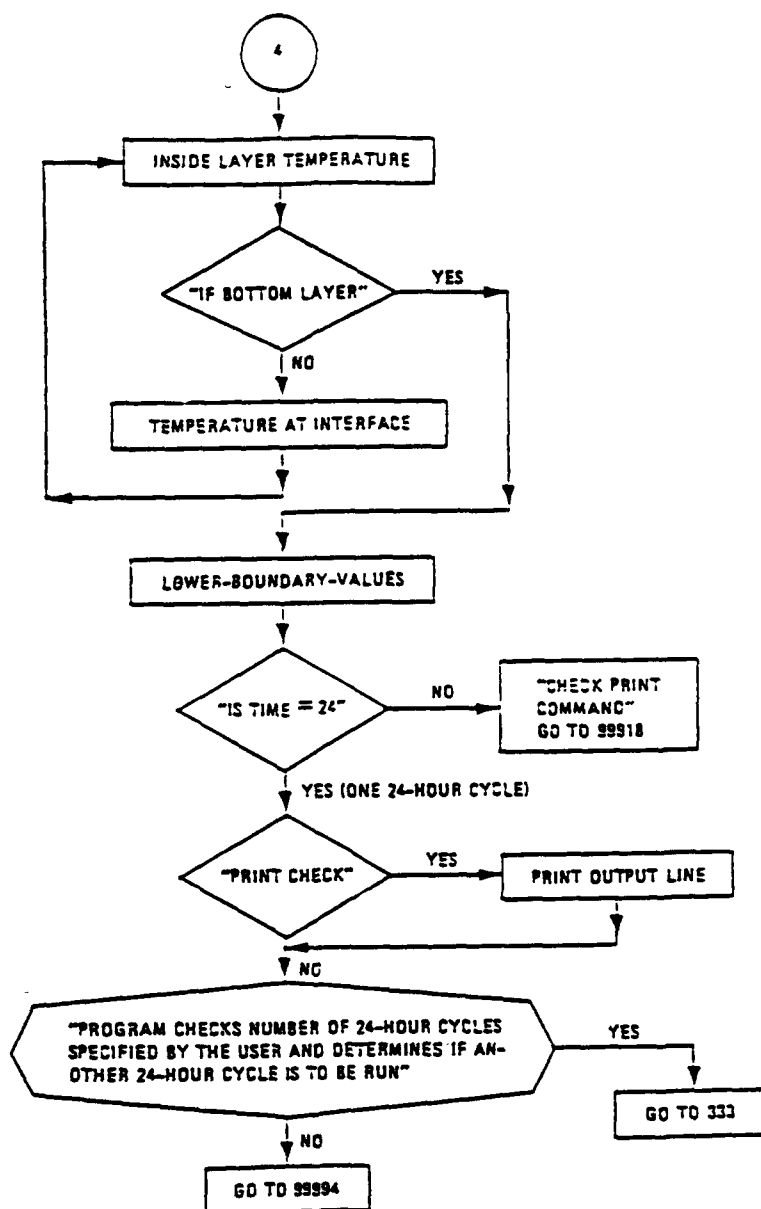


Figure 3.2. Simplified flowchart for TSTM, Balick *et al.*, 1981a (sheet 5 of 5).

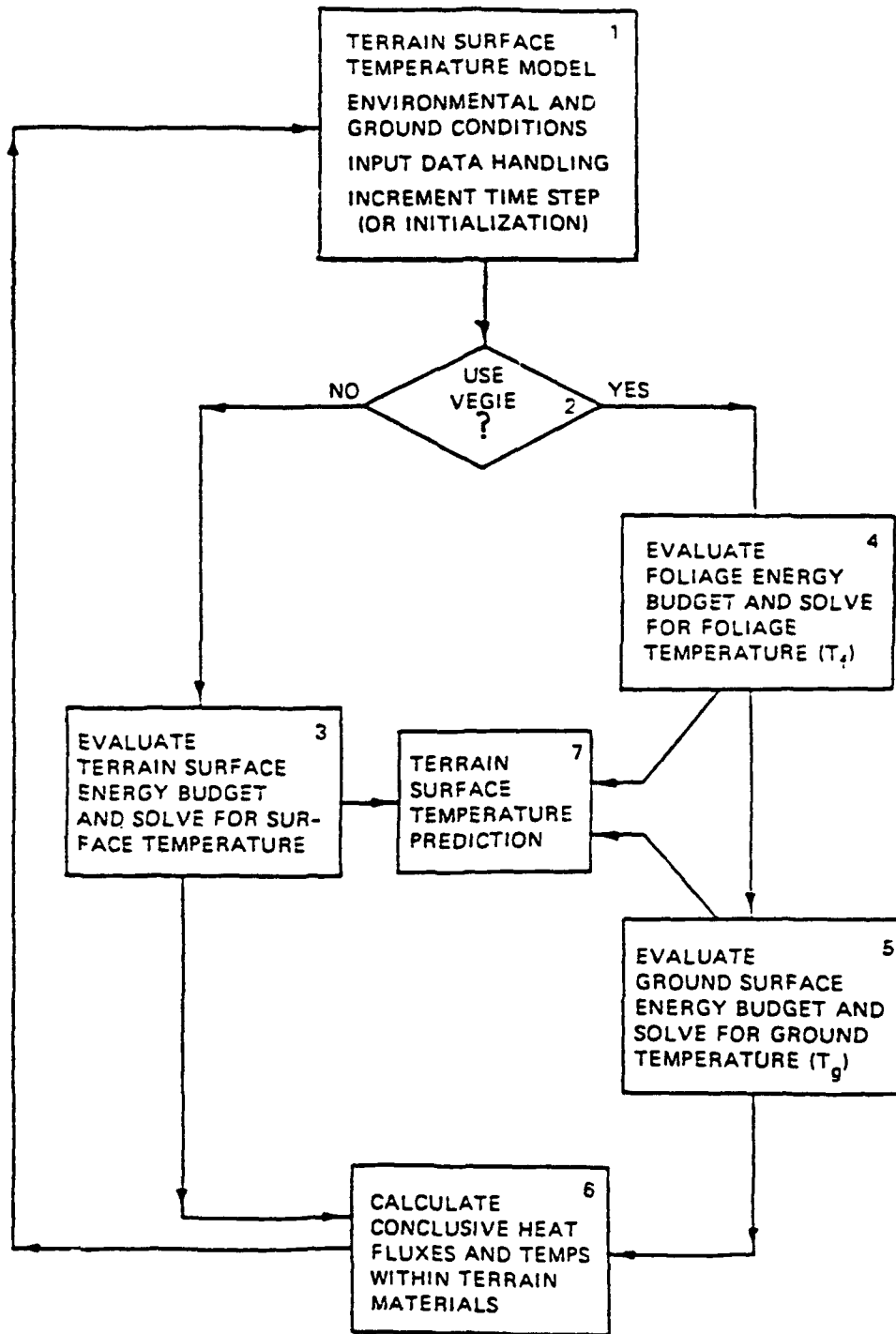


Figure 3.3. Sequence of calculation of the major components of the TSTM/VEGIE system, Balick *et.al.* (1981b).

In block 1 the model is incremented one time step or initialized, or terminated) in accordance with procedures established for TSTM. In block 2 the decision whether to utilize VEGIE or not is made. If VEGIE is not used a non-vegetated surface energy budget is evaluated as an upper boundary condition (block 3) for the solution of the equation of heat transfer through the terrain materials (block 6). The solution for the surface temperature (block 7) comes from the evaluation of the surface energy budget equation and therefore to solve the heat transfer equation. In order to achieve this the heat conduction term and the distribution of heat in terrain materials must be calculated (block 6). If VEGIE is used, the energy budget of block 3 is replaced by blocks 4 and 5. Blocks 4 and 5 comprise VEGIE. Block 4 calculates the energy budget for the foliage that includes a contribution from the ground surface. Block 5 calculates the energy budget for the ground surface that includes a contribution from the foliage layer.

Solutions of temperature for the foliage (from block 4) and the ground (from block 5) are performed by a simple root-finding algorithm and are combined according to the proportion of foliage cover to yield an average, or effective, temperature of the vegetated surface. The ground energy budget is then used in the evaluation of heat flow in the terrain (block 6), and the programme returns to block 1.

### 3.2. Additional information.

SNOMO can be altered very simply in order to produce, in the output file, the hourly energy budget values for the snowpack of  $K\downarrow$ ,  $K\uparrow$ ,  $L\downarrow$ ,  $L\uparrow$ ,  $Q_c$  and  $Q_e$ . The alterations are found under the heading 'OPTION 2' in the hardcopy of the programme (section 3.3.)

The absence of a mass conservation routine was discussed in volume 1. A mass conservation routine has been written and tested (chapter 7, volume 1) and is included in the hardcopy of the

programme (section 3.3.) as 'OPTION 3'.

### 3.3. Programme code.

Copies of *snomo.f*, *snomo.dat*, *decid.dat*, *conif.dat*, *mix.dat*, *lapse.dat* and *SNOMO.RES* are available on the floppy disc inserted at the back of this volume. A fully commented hardcopy of the programme code is presented in the following pages.

-----  
 C  
 C SNOMO.F, JUNE 1981  
 C BY  
 C KATHERINE M. SAMBLES  
 C-----

C  
 C THIS IS A DISTRIBUTED PHYSICALLY-BASED SNOWMELT MODEL. SNOMO.F IS  
 C DESIGNED TO OPERATE IN CONJUNCTION WITH A GIS DECISION AND DATA  
 C MANIPULATION STRUCTURE WHICH DIVIDES THE CATCHMENT THAT IS TO BE  
 C MODELLED INTO HOMOGENEOUS SUBDIVISIONS, CALLED CELLS. SNOMO.F  
 C CALCULATES THE ENERGY-BUDGET OF THE SNOWPACK AT THE MID-POINT OF  
 C ONE CELL AND CALCULATES THE RESULTANT CHANGE IN SNOWPACK PROPERTIES  
 C AND MELTWATER RUNOFF. USING THE RESULTS FOR EACH CELL AND THE GIS  
 C STRUCTURE A MAP OF THE SNOWCOVER DISTRIBUTION AND DEPTH DISTRIBUTION  
 C CAN BE OBTAINED. SNOMO.F IS DEVELOPED FROM THE WES MODEL TSTM AND  
 C THE SUBMODEL VEGIE WAS INCORPORATED INTO SNOMO.F IN MARCH 1989 WITH  
 C THE HELP OF DR. RANDY SCOGGINS, WES.

C  
 C SNOMO.F IS DIVIDED INTO 2 MAJOR PARTS:  
 C (1) THE MAIN PROGRAM. THIS CALCULATES MELT, MANIPULATES THE  
 C SNOWPACK DEPTH AND PHYSICAL CHARACTERISTICS AND HANDLES THE  
 C MODEL INPUT AND OUTPUT.  
 C (2) THE SUBROUTINE TSTM. THIS CALCULATES THE COMPONENTS OF THE  
 C ENERGY-BUDGET OF THE SNOWPACK.  
 C SNOMO.F REQUIRES THE DATA FILES SNOMO.DAT, LAPSE.DAT, DECID.DAT,  
 C MIX.DAT AND COMIF.DAT IN ORDER TO OPERATE. THE OUTPUT FILE IS  
 C SNOMO.RES. A FULL LISTING OF ALL THE VARIABLES USED IS INCLUDED  
 C AT THE END OF THE PROGRAM CODE.  
 C THERE ARE 3 CODE OPTIONS FOR SNOMO.F:  
 C OPTION 1 IS THE DEFAULT OPTION. OPTION 1 IS UTILISED UNLESS OTHERWISE STATED.  
 C OPTION 2 GIVES AN OUTPUT OF HOURLY ENERGY-BUDGET VALUES.  
 C OPTION 3 INCLUDES A MASS CONSERVATION ROUTINE.

C  
 C-----  
 C  
 C INITIALISATION, DECLARATION, DATA STATEMENTS.  
 C

```
COMMON/MATRX1/XXX(30,10),YYY(30,10)
COMMON/MATRX2/DEPMK1(2,2),DEPMK2(3,2)
COMMON/MATRX3/THQMK1(1,6),THQMK2(2,6)
COMMON/VECTOR/VNEWSN(1,6),VOLDSN(1,6)
COMMON/TSTM1/PRESS,NCLOUD,ZA,SLOPE1,SURFC1,DAY,LAT
COMMON/TSTM2/WOMATL,NIPTS
COMMON/VEGI/IVEG,SIGF,STATE,EFF,ALBEDO,HPOL
COMMON/RAIN/AIRTP
COMMON/SFRQ/SFRQ(6)
REAL SPPFW,SNVOL,CRITDP,BCAPSW,DENSW,
& DENW,BCAPW,LELATP,DEPTH,PTERM,NETRAD,AVSTP,
& AVSTTP,PFTW,DAY1,LAT,TGER,TSOL,TABSOR,IATERM,ITERM,
& TDTERM,VBOIL(1,6),WE1,DEPTH1,MHME,MRSN,BOTTP,STP,XSWTP,
& SPHT1,SPHTW,SHDP1,TMAX,TMIN
```

INTEGER I, J, N, K1, K2, K3, K10, K30, KONTRL, ILAPSE, IVEG, ISNOW,  
& IBRAIN, CELL, YEAR

C

C LATENT HEAT OF FUSION IS  $0.334 \text{ MJkg}^{-1}$   
C SPECIFIC HEAT OF ICE IS GIVEN IN  $\text{MJkg}^{-1}\cdot\text{K}^{-1} = 2.10\text{E}+3 \text{ Jkg}^{-1}\cdot\text{K}^{-1}$   
C SPECIFIC HEAT OF WATER IS GIVEN IN  $\text{KJkg}^{-1}\cdot\text{K}^{-1} = 4.18\text{E}+3 \text{ Jkg}^{-1}\cdot\text{K}^{-1}$

C

DATA DENW, BCAPW, BCAPSN, LHEATF/1000.0, 4.21, 2.09, 0.334/  
DATA SPHTI, SPHTW/0.0021, 4.18/  
DATA TOTTIM, TFRQ, TPRNT/1.1.0, 60.0/  
NIN=10  
NCONIF=11  
NLAPSE=12  
NDECID=13  
NMIX=14  
NOUT=9  
OPEN(UNIT=NIN, FILE='SNOW.DAT', STATUS='OLD')  
REWIND NIN  
OPEN(UNIT=NCONIF, FILE='CONIF.DAT', STATUS='OLD')  
REWIND NCONIF  
OPEN(UNIT=NLAPSE, FILE='LAPSE.DAT', STATUS='OLD')  
REWIND NLAPSE  
OPEN(UNIT=NDECID, FILE='DECID.DAT', STATUS='OLD')  
REWIND NDECID  
OPEN(UNIT=NMIX, FILE='MIX.DAT', STATUS='OLD')  
REWIND NMIX  
OPEN(UNIT=NOUT, FILE='SNOW.RES')  
REWIND NOUT

C

READ(10, \*)CELL, YEAR

C

C VECTORS VNEWSN, VOLDSN AND VSOIL CONTAIN THE PHYSICAL  
C PROPERTIES OF NEW SNOW, OLD SNOW AND SOIL RESPECTIVELY.  
C VECTOR(1,1)= 0.0  
C VECTOR(1,2)= SNOW/SOIL THERMAL DIFFUSIVITY,  $\text{cm}^2 \text{min}^{-1}$   
C VECTOR(1,3)= SNOW/SOIL HEAT CONDUCTIVITY,  $\text{calcm}^{-2} \text{min}^{-1}\cdot\text{K}^{-1}$   
C VECTOR(1,4)= SNOW/SOIL EMISSIVITY, DECIMAL  
C VECTOR(1,5)= SNOW/SOIL ALBEDO, DECIMAL  
C VECTOR(1,6)= SNOW/SOIL DENSITY,  $\text{gcm}^{-3}$

C

READ(10,\*)((VNEWSN(I,J), J=1,6), I=1,1)  
READ(10,\*)((VOLDSN(I,J), J=1,6), I=1,1)  
READ(10,\*)((VSOIL(I,J), J=1,6), I=1,1)  
READ(10,\*)PRESS, N\_CLOUD, ZA  
READ(10,\*)SLOPE1, SURFC1, DAY1, LAT  
READ(10,\*)ILAPSE  
READ(10,\*)IVEG  
READ(10,\*)SNDF1

C

C IVEG DETERMINES WHICH VEGETATION DATA FILE IS USED:  
C IVEG=1, CONIF.DAT (CONIFEROUS DATA)  
C IVEG=2, DECID.DAT (DECIDUOUS DATA)

```

C IVEG=3, MIX.DAT (MIXED DATA)
C IVEG=0, NO VEGETATION DATA FILE IS USED, THE VEGETATION IS
C MODELLED AS PASTURE (OPEN) AND CLEARCUT.
C ILAPSE DETERMINES WHICH ELEVATION DATA FILE IS USED TO
C MODIFY THE AIR TEMPERATURES WITH LAPSE RATE. THE PRESENT
C USE OF ILAPSE REFERS SOLELY TO THE APPLICATION OF SNOMO.F TO
C THE W3 CATCHMENT.
C ILAPSE=0, ELEVATION BAND 1500-2000FT. THIS IS THE ELEVATION
C BAND OF THE METEOROLOGICAL STATION THAT PROVIDES THE INPUT
C DATA, THEREFORE NO CHANGES ARE MADE TO THE AIR TEMPERATURES.
C ILAPSE=1, ELEVATION BAND 1000-1500FT. THIS INCREASES THE
C MAX. AIR TEMP. BY 2°F AND THE MIN. BY 1°F.
C
  IF(IVEG.EQ.1)THEN
    READ(11,*)SIGF,STATE,EFF,ALBEDO,HFOL
  ELSE
    IF(IVEG.EQ.2)THEN
      READ(13,*)SIGF,STATE,EFF,ALBEDO,HFOL
    ELSE
      IF(IVEG.EQ.3)THEN
        READ(14,*)SIGF,STATE,EFF,ALBEDO,HFOL
      END IF
    END IF
  END IF
  IF(ILAPSE.GT.0)THEN
    READ(12,*)TMAX,TMIN
  END IF
  READ(10,*)CRITDP
  READ(10,*)SOILD,SOILTP,SSOLTP
  READ(10,*)N
C
C N= NUMBER OF DAYS TO BE MODELLED IE. NO. OF DAYS IN DATA FILE
C MINUS ONE.
C DAILY METEOROLOGICAL DATA.
C XXX(1,8)= JULIAN DATE
C XXX(1,1)= OBSERVATION TIME, 24HR CLOCK
C YYY(1,1)= MINIMUM AIR TEMPERATURE, °C
C YYY(1,9)= MAXIMUM AIR TEMPERATURE, °C
C YYY(1,2)= RELATIVE HUMIDITY, %
C YYY(1,3)= CLOUD COVER, 0-1
C YYY(1,6)= WIND SPEED, m/s
C YYY(1,7)= PRECIPITATION, mm WATER
C
  READ(10,*)XXX(1,8),XXX(1,1),YYY(1,1),YYY(1,9),YYY(1,2),
  & YYY(1,3),YYY(1,6),YYY(1,7)
  READ(10,*)XXX(2,8),XXX(2,1),YYY(2,1),YYY(2,9),YYY(2,2),
  & YYY(2,3),YYY(2,6),YYY(2,7)
C
C SIMPLE MODIFICATION OF AIR TEMPERATURES FOR LAPSE RATE
  IF(ILAPSE.EQ.0)THEN
    GOTO 5
  ELSE

```



```

C CONVERT °C TO °F
  YYY(1,1)=((YYY(1,1)*9.0)/5.0)+32.0
  YYY(1,9)=((YYY(1,9)*9.0)/5.0)+32.0
  YYY(2,1)=((YYY(2,1)*9.0)/5.0)+32.0
  YYY(2,9)=((YYY(2,9)*9.0)/5.0)+32.0
  IF(ILAPSE.EQ.1)THEN
    YYY(1,1)=YYY(1,1)+TMIN
    YYY(1,9)=YYY(1,9)+TMAX
    YYY(2,1)=YYY(2,1)+TMIN
    YYY(2,9)=YYY(2,9)+TMAX
  ELSE
    YYY(1,1)=YYY(1,1)-TMIN
    YYY(1,9)=YYY(1,9)-TMAX
    YYY(2,1)=YYY(2,1)-TMIN
    YYY(2,9)=YYY(2,9)-TMAX
  END IF
C CONVERT °F TO °C
  YYY(1,1)=((YYY(1,1)-32.0)/9.0)*5.0
  YYY(1,9)=((YYY(1,9)-32.0)/9.0)*5.0
  YYY(2,1)=((YYY(2,1)-32.0)/9.0)*5.0
  YYY(2,9)=((YYY(2,9)-32.0)/9.0)*5.0
  END IF
C
C THE SNOWDEPTH AND THE PHYSICAL PROPERTIES OF THE
C SNOWPACK ARE HELD IN THE MATRICES DEPMK1, DEPMK2
C (HOLDING THE SNOWDEPTH AND CORRESPONDING TEMPERATURE)
C AND THKM1, THKM2 (HOLDING THE THICKNESS OF THE LAYERS
C OF THE PACK AND THE CORRESPONDING PHYSICAL PROPERTIES,
C IE. VNEWSN OR VOLDEN). THE NUMBERS 1 AND 2 REFER TO
C EITHER A 1- OR 2-LAYERED PACK, FOR A 1-LAYERED PACK
C NOMATL=1 AND NIPTS=2, FOR A 2-LAYERED PACK NOMATL=2,
C NIPTS=3.
C SET 2-LAYER SNOW THICKNESS MATRIX TO ZERO
C SET 2-LAYER DEPTH MATRIX TO ZERO
C
5   DO 20 I=1,2
      DO 10 J=1,6
          THKM2(I,J)=0.0
10  CONTINUE
20  CONTINUE
      DO 40 I=1,3
          DO 30 J=1,2
              DEPMK2(I,J)=0.0
30  CONTINUE
40  CONTINUE
C
C SET CONTROLS TO ZERO
C WRITE HEADER FOR RESULTS FILE
C
      KONTRL=0
      SNVOL=0.0
      DEPTH=0.0

```

```

K1=0
K2=0
K25=0
WRITE(9,*)'CELL NO.:',CELL
WRITE(9,*)'YEAR:',YEAR
WRITE(9,*)'JULIAN      SNOWDEPTH      SNOWMELT      SNOWFALL
& DENSITY RAIN-ON-SNOW'
WRITE(9,*)' DATE      (CM)      (CM SNOW) (MM WATER) (CM)
& (G/M**3) (1=YES, 0=NO)'
C
C DAILY CALCULATION LOOP
C
DO 5001 L=1,N
  K1=K1+1
  K30=0
  KELVIN=YYY(1,1)+273.15
  PPTN=YYY(1,7)
  AIRTP=YYY(1,1)
  DDATE=XXX(1,8)
  TIME2=XXX(2,1)
C
C LOGIC STRUCTURE TO INITIALISE SNOWDEPTH
C
  IF(K3.EQ.1)THEN
    K2=0
    GOTO 57
  ELSE
    IF(PPTN.GT.0.0.AND.AIRTP.LT.0.0)THEN
      SNPPTN=(PPTN/VNEWSN(1,6))/10
      END IF
    END IF
    IF(K1.EQ.1)THEN
      K2=0
      SNPPTN=SNDF1
      END IF
      DEPTH=SNPPTN+DEPTH
      IF(DEPTH.GE.CRITDP)THEN
        IF(DEPTH.GT.CRITDP)THEN
          NOMATL=2
          NIPTS=3
          DEPMK2(1,1)=0.0
          DEPMK2(1,2)=AIRTP
          DEPMK2(2,1)=5.0
          DEPMK2(2,2)=AIRTP
          DEPMK2(3,1)=SNPPTN
          DEPMK2(3,2)=SSOLT
          XSWTP=((DEPMK2(1,2)+DEPMK2(3,2))/2)+273.15
          DO 53 J=1,6
            THPMK2(1,J)=VNEWSN(1,J)
            THPMK2(2,J)=VOLDEN(1,J)
          53 CONTINUE
          THPMK2(1,1)=5.0

```

```

      THKMK2(2,1)=SNPPTN-5.0
      ELSE
      NOMATL=1
      NIPTS=2
      DEPMK1(1,1)=0.0
      DEPMK1(1,2)=AIRTP
      DEPMK1(2,1)=DEPTH
      DEPMK1(2,2)=SSOLTP
      XSNTP=((DEPMK1(1,2)+DEPMK1(2,2))/2)+273.15
      DO 54 J=1,6
      THKMK1(1,J)=VNEWSN(1,J)
54    CONTINUE
      THKMK1(1,1)=DEPTH
      END IF
      ISNOW=ISNOW+1
      K25=0
      K3=1
      K2=1
      GOTO 57
      ELSE
      NOMATL=1
      NIPTS=2
      DO 56 J=1,6
      THKMK1(1,J)=VSOIL(1,J)
56    CONTINUE
      THKMK1(1,1)=SOILDP
      DEPMK1(1,1)=0.0
      DEPMK1(1,2)=AIRTP
      DEPMK1(2,1)=SOILDP
      DEPMK1(2,2)=SOILTTP
      K3=0
      K2=0
      END IF
C
C CALL SUBROUTINE CSFRQ, TO CALCULATE SFRQ
C
57    CALL CSFRQ(I,N)
C
C SET DEPTH MATRICES AND VARIABLES TO ZERO
C
      IF(NOMATL.EQ.1)THEN
      DO 59 I=1,3
      DO 58 J=1,2
      DEPMK2(I,J)=0.0
58    CONTINUE
59    CONTINUE
      ELSE
      DO 61 I=1,2
      DO 60 J=1,2
      DEPMK1(I,J)=0.0
60    CONTINUE
61    CONTINUE

```

```

      END IF
      K10=0
      AVSTP=0.0
      STP=0.0
      AVSOL=0.0
      AVGER=0.0
      AVABSR=0.0
      AVATER=0.0
      AVHTER=0.0
      AVDTER=0.0
      AVBTTP=0.0
      BOTTP=0.0

C
C CALL SUBROUTINE TSTM, TO CALCULATE THE SHORTWAVE, LONGWAVE, LATENT
C HEAT AND SENSIBLE HEAT EXCHANGES AT THE SURFACE OF THE SNOWPACK AND
C HEAT TRANSPORT THROUGH THE PACK. IN SNOMO TSTM CAN MODEL THESE
C EXCHANGES FOR EITHER SNOW OR SOIL.
C
      CALL TSTM(I,'Y','N',K10,AVSTP,AVSOL,AVGER,AVABSR,AVATER,
& AVHTER,AVDTER,K2,AVBTTP,TGER,TSOL,TABSOR,
& TATERM,HTERM,TDTERM)

C
C PROGRAM CONTINUES IF SNOW WAS MODELLED BY TSTM, JUMPS TO THE NEXT DAY
C IF SOIL WAS MODELLED
C
      IF(K3.EQ.0)THEN
        GOTO 9000
      ELSE
        K3=1
      END IF

C
C CALL SUBROUTINE CMELT, TO CALCULATE THE MELT RATE. THE ENERGY
C INTRODUCED TO THE PACK BY RAIN (PTERM) IS NOT INCLUDED AT THIS STAGE
C MELT RATE IS CALCULATED IN CM OF SNOW AND MM OF WATER EQUIVALENT.
C
      PTERM=0.0
      CALL CMELT(I,N,NETRAD,PTERM,TSOL,TGER,TABSOR,
& TATERM,HTERM,TDTERM,PPTN,DENSN,MRWE,MRSN,GTERM,DEW,DEPTH,
& AVSTP,AVBTTP,XSNTP,SPHTI,K30)
      IRAIN=0

C
C CALL SUBROUTINE RAINMP, TO CALCULATE THE ENERGY INTRODUCED TO THE
C MELTING PACK BY RAIN, IF RAIN OCCURED. THE MELT RATE IS RECALCULATED.
C
      IF(PPTN.GT.0.0.AND.AIRTP.GT.0.0)THEN
        IF(MRWE.GT.0.0)THEN
          IRAIN=1
          CALL RAINMP(I,N,PPTN,PTERM,DEW,K30)
          CALL CMELT(I,N,NETRAD,PTERM,TSOL,TGER,TABSOR,
& TATERM,HTERM,TDTERM,PPTN,DENSN,MRWE,MRSN,GTERM,DEW,
& DEPTH,AVSTP,AVBTTP,XSNTP,SPHTI,K30)
          END IF
        END IF

```

```

      END IF
C
C CALCULATION OF SNOWFALL IF NOT FIRST ITERATION OR SOIL MODELLED
C IN THE PREVIOUS ITERATION.
C
      IF(AVSTP.GT.0.0)THEN
      AVSTP=0.0
      END IF
      IF(K2.EQ.0)THEN
      IF(PPTN.GT.0.0.AND.AIRTP.LT.0.0)THEN
      SNPPTN=(PPTN/VNEWSN(1,6))/10
      K25=0
      ELSE
      SNPPTN=0.0
      K25=K25+1
      END IF
      END IF
C
C LOGIC STRUCTURE TO ALLOW FOR THE EFFECTS OF SNOWFALL
C
      IF(K1.EQ.1)THEN
      DEPMK2(1,2)=AVSTP
      DEPMK2(3,2)=AVBTTP
      DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
      GOTO 3000
      END IF
      IF(SNPPTN.GT.0.0)THEN
      IF(NOMATL.EQ.1)THEN
      IF(THICK1(1,2).EQ.VNEWSN(1,6))THEN
      IF(ISNOW.GT.0)THEN
      THICK1(1,1)=THICK1(1,1)+SNPPTN
      DEPTH=DEPTH+SNPPTN
      DEPMK1(2,1)=DEPTH
      DEPMK1(1,2)=AVSTP
      DEPMK1(2,2)=AVBTTP
      GOTO 4000
      ELSE
      WE1=(THICK1(1,1)*10)*VNEWSN(1,6)
      DEPTH1=(WE1/VOLDSN(1,6))/10
      NOMATL=2
      NIPTS=3
      DO 70 J=1,6
      THICK2(1,J)=VNEWSN(1,J)
      THICK2(2,J)=VOLDSN(1,J)
70
      CONTINUE
      THICK2(1,1)=SNPPTN
      THICK2(2,1)=DEPTH1
      DEPTH=SNPPTN+DEPTH1
      DEPMK2(1,2)=AVSTP
      DEPMK2(3,2)=AVBTTP
      DEPMK2(3,1)=DEPTH
      DEPMK2(2,1)=THICK2(1,1)

```

```

      DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
      GOTO 3000
    END IF
  ELSE
    NOMATL=2
    NIPTS=3
    DO 80 J=1,6
      THQMK2(1,J)=VNEWSN(1,J)
      THQMK2(2,J)=VOLDN(1,J)
80    CONTINUE
    THQMK2(1,1)=SNPPTN
    THQMK2(2,1)=DEPTH
    DEPTH=DEPTH+SNPPTN
    DEPMK2(1,2)=AVSTP
    DEPMK2(3,2)=AVBTTP
    DEPMK2(3,1)=DEPTH
    DEPMK2(2,1)=THQMK2(1,1)
    DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
    GOTO 3000
  END IF
ELSE
  IF (ISNOW.GT.0) THEN
    THQMK2(1,1)=THQMK2(1,1)+SNPPTN
    DEPTH=DEPTH+SNPPTN
    DEPMK2(3,1)=DEPTH
    DEPMK2(2,1)=THQMK2(1,1)
    DEPMK2(2,2)=AVSTP
    DEPMK2(3,2)=AVBTTP
    DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
    GOTO 3000
  ELSE
    WE1=(THQMK2(1,1)*10)*VNEWSN(1,6)
    DEPTH1=(WE1/VOLDN(1,6))/10
    THQMK2(2,1)=THQMK2(2,1)+DEPTH1
    THQMK2(1,1)=SNPPTN
    DEPTH=THQMK2(2,1)+THQMK2(1,1)
    DEPMK2(3,1)=DEPTH
    DEPMK2(2,1)=THQMK2(1,1)
    DEPMK2(1,2)=AVSTP
    DEPMK2(3,2)=AVBTTP
    DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
    GOTO 3000
  END IF
END IF
ELSE
  IF (NOMATL.EQ.1) THEN
    IF (THQMK1(1,2).EQ.VNEWSN(1,6)) THEN
      IF (ISNOW.GE.1) THEN
        DEPMK1(1,2)=AVSTP
        DEPMK1(2,2)=AVBTTP
        GOTO 4000
      ELSE

```

```

WE1=(THQK1(1,1)*10)*VNEWSN(1,6)
DEPTH1=(WE1/VOLDSN(1,6))/10
DEPTH=DEPTH1
DO 250 J=1,6
  THQK1(1,J)=VOLDSN(1,J)
250  CONTINUE
  THQK1(1,1)=DEPTH
  DEPK1(1,2)=AVSTP
  DEPK1(2,2)=AVBTTP
  DEPK1(2,1)=DEPTH
  GOTO 4000
  END IF
ELSE
  DEPK1(1,2)=AVSTP
  DEPK1(2,2)=AVBTTP
  GOTO 4000
  END IF
ELSE
  IF(ISNOW.GT.0)THEN
    DEPK2(1,2)=AVSTP
    DEPK2(3,2)=AVBTTP
    DEPK2(2,2)=((DEPK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
    GOTO 3000
  ELSE
    WE1=(THQK2(1,1)*10)*VNEWSN(1,6)
    DEPTH1=(WE1/VOLDSN(1,6))/10
    DEPTH=DEPTH1+THQK2(2,1)
    NOMATL=1
    NIPTS=2
    DO 350 J=1,6
      THQK1(1,J)=VOLDSN(1,J)
350  CONTINUE
      THQK1(1,1)=DEPTH
      DEPK1(1,2)=AVSTP
      DEPK1(2,2)=AVBTTP
      DEPK1(2,1)=DEPTH
      GOTO 4000
    END IF
  END IF
END IF

C
C LOGIC STRUCTURE TO ALLOW FOR THE EFFECTS OF SNOWMELT
C ON A 2-LAYER PACK.
C
3000  IF(DEPTH.LE.5.0)THEN
      GOTO 5002
    END IF
C*****
C OPTION 3-MASS CONSERVATION ROUTINE.
C IF OPTION 3 REQUIRED INSERT MASS CONSERVATION ROUTINE TO REPLACE
C ALL CODE BETWEEN THE *****LINES.
C

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```

3001  IF(MRSN.GE.DEPTH)THEN
      GOTO 5002
      ELSE
        IF(MRSN.LE.0.0)THEN
          DEPMK2(1,2)=AVSTP
          DEPMK2(3,2)=AVBTTP
          DEPMK2(3,1)=DEPTH
          DEPMK2(2,1)=THQMK2(1,1)
          DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
          THQMK2(2,1)=DEPTH-THQMK2(1,1)
          GOTO 3500
        ELSE
          IF(MRSN.GE.THQMK2(1,1))THEN
            NCMAIL=1
            NIPTS=2
            DO 400 J=1,8
              THQMK1(1,J)=VOLDNS(1,J)
400    CONTINUE
            DEPTH=DEPTH-MRSN
            THQMK1(1,1)=DEPTH
            DEPMK1(1,2)=AVSTP
            DEPMK1(2,2)=AVBTTP
            DEPMK1(2,1)=THQMK1(1,1)
            ELSE
              THQMK2(1,1)=THQMK2(1,1)-MRSN
              DEPTH=THQMK2(1,1)+THQMK2(2,1)
              DEPMK2(1,2)=AVSTP
              DEPMK2(3,2)=AVBTTP
              DEPMK2(3,1)=DEPTH
              DEPMK2(2,1)=THQMK2(1,1)
              DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBTTP-AVSTP))+AVSTP
            END IF
3500    GOTO 5000
          END IF
        END IF
      C
      C LOGIC STRUCTURE TO ALLOW FOR THE EFFECTS OF SNOWMELT
      C ON A 1-LAYER PACK.
      C
4000  IF(DEPTH.LE.5.0)THEN
      GOTO 5002
      END IF
4001  IF(MRSN.GE.DEPTH)THEN
      GOTO 5002
      ELSE
        IF(MRSN.LE.0.0)THEN
          DEPMK1(1,2)=AVSTP
          DEPMK1(2,2)=AVBTTP
          DEPMK1(2,1)=THQMK1(1,1)
        ELSE
          DEPTH=DEPTH-MRSN
          THQMK1(1,1)=DEPTH

```



```

DEPMK1(1,2)=AVSTP
DEPMK1(2,2)=AVBTTP
DEPMK1(2,1)=THMK1(1,1)
END IF
END IF

C
C IF TOP LAYER OF 2-LAYER PACK IS <1CM THICK THEN PACK IS
C CONVERTED INTO 1-LAYER PACK.
C
5000 IF(NOMATL.EQ.2.AND.THMK2(1,1).LT.1.0)THEN
      DEPTH=THMK2(1,1)+THMK2(2,1)
      NOMATL=1
      NIPTS=2
      DO 450 J=1,6
        THMK1(1,J)=VOLDEN(1,J)
450   CONTINUE
      THMK1(1,1)=DEPTH
      DEPMK1(2,1)=DEPTH
      DEPMK1(1,2)=AVSTP
      DEPMK1(2,2)=AVBTTP
      END IF

C
C MELTRATE CANNOT BE NEGATIVE.
C
      IF(MRSE.LT.0.0)THEN
        MRSE=0.0
      END IF
      IF(MRNE.LT.0.0)THEN
        MRNE=0.0
      END IF
550   FORMAT(6F6.2)
555   FORMAT(2F6.2)
C*****
C END OF OPTION 3 CODE INSERTION.
C
C
C READ IN NEXT DAILY DATA LINE, SHIFTING EXISTING BOTTOM
C DATA LINE TO THE TOP. EXIT PROGRAM IF LAST DATA LINE
C REACHED.
C
9000   YYY(2,6)=YYY(2,6)/100.0
      YYY(2,2)=YYY(2,2)*100
      XXX(1,8)=XXX(2,8)
      XXX(1,1)=TIME2
      YYY(1,1)=YYY(2,1)
      YYY(1,2)=YYY(2,2)
      YYY(1,9)=YYY(2,9)
      YYY(1,3)=YYY(2,3)
      YYY(1,6)=YYY(2,6)
      YYY(1,7)=YYY(2,7)
      XXX(2,8)=0
      XXX(2,1)=0

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```

      YYY(2,1)=0
      YYY(2,9)=0
      YYY(2,2)=0
      YYY(2,3)=0
      YYY(2,6)=0
      YYY(2,7)=0
      NKONT=N-KONTL
      IF(NKONT.EQ.1)THEN
      GOTO 5002
      END IF
      YYY(1,1)=YYY(1,1)-273.15
      YYY(1,9)=YYY(1,9)-273.15
      READ(10,*)XXX(2,8),XXX(2,1),YYY(2,1),YYY(2,9),YYY(2,2),
& YYY(2,3),YYY(2,6),YYY(2,7)
C
C CONVERT AIR TEMPERATURE FOR LAPSE RATE
C
      IF(ILAPSE.EQ.0)THEN
      GOTO 90
      ELSE
C CONVERT °C TO °F
      YYY(2,1)=((YYY(2,1)*9.0)/5.0)+32.0
      YYY(2,9)=((YYY(2,9)*9.0)/5.0)+32.0
      IF(ILAPSE.EQ.1)THEN
      YYY(2,1)=YYY(2,1)+TMIN
      YYY(2,9)=YYY(2,9)+TMAX
      ELSE
      YYY(2,1)=YYY(2,1)-TMIN
      YYY(2,9)=YYY(2,9)-TMAX
      END IF
C CONVERT °F TO °C
      YYY(2,1)=((YYY(2,1)-32.0)/9.0)*5.0
      YYY(2,9)=((YYY(2,9)-32.0)/9.0)*5.0
      END IF
C
C REINITIALISATION OF CERTAIN VARIABLES, WRITE OUT RESULTS.
C
90  IF(K2.EQ.0)THEN
      IF(SNPPIN.GT.0.0)THEN
      ISNOW=ISNOW+1
      ELSE
      ISNOW=0
      END IF
      END IF
      AIRTP=YYY(1,1)
      KELVIN=YYY(1,1)+273.15
      PPTN=YYY(1,7)
      DDATE=XXX(1,8)
      KONTL=KONTL+1
      SNOW=SNPPIN
      SNPPIN=0.0
      WRITE(9,333)DDATE-1,DEPTH,MRSN,MONE,SNOW,DENSN,IRAIN

```

```
333  FORMAT(F6.2,5X,F6.2,4X,F6.2,4X,F6.2,4X,F6.2,7X,F6.2,5X,I3)
5001  CONTINUE
5002  WRITE(0,*)'PROGRAM TERMINATION'
      STOP
      END
C
C -----
```

```

C
C SUBROUTINE CMELT
C -----
C THIS CALCULATES THE MELTRATE IN CM OF SNOW AND MM OF WATER EQUIVALENT.
C THE DENSITY OF THE SNOWPACK IS CALCULATED IF THE PACK IS A 2-LAYERED
C PACK. MELT IS CALCULATED USING THE SNOW ENERGY-BUDGET. MOST OF
C THE COMPONENTS OF THE SNOW ENERGY-BUDGET ARE CALCULATED BY TSTM, THE
C EXCEPTIONS ARE PTERM AND DELQS. THE ENERGY UNITS ARE MJm-2day-1.
C
SUBROUTINE CMELT(I,N,WETRAD,PTERM,TSOL,TGER,TABSOR,
& TATERM,ITERM,TDTERM,PFTH,DENSN,MREWE,MRSN,GTERM,DENW,DEPTH,
& AVSTP,AVBTTP,XSWTP,SPHTI,K30)
COMMON/MATRX2/DEPMK1(2,2),DEPMK2(3,2)
COMMON/MATRX3/THMK1(1,6),THMK2(2,6)
COMMON/TSTM2/NOMATL,NIPTS
REAL LHEATF,WETRAD,MREWE,MRSN,DEPTH,DENSN,A,B,C,D,
& XSWTP1,DELQS,DELRWE,DELRW,XSWTP
DATA LHEATF,BCAPW,BCAPSW/0.334,4.21,2.09/
GTERM=0.0
C
C CALCULATION OF THE DENSITY OF SNOW
C
IF(NOMATL.EQ.1)THEN
DENSN=THMK1(1,6)
ELSE
A=THMK2(1,1)/DEPTH
B=THMK2(2,1)/DEPTH
C=A*THMK2(1,6)
D=B*THMK2(2,6)
DENSN=C+D
END IF
C
C CALCULATION OF DELQS IN Jm-2day-1, THEN CONVERTED TO MJm-2dy-1
C
IF(K30.EQ.1)THEN
K30=0
GOTO 10
ELSE
XSWTP1=XSWTP
XSWTP=((AVSTP+AVBTTP)/2)+273.15
DELQS=((DEPTH*0.01)*(DENS*1000))*((SPHTI*XSWTP)-
& (SPHTI*XSWTP1))
END IF
C
C CALCULATION OF THE ENERGY-BUDGET OF THE SNOWPACK AND THE MELT RATE.
C MULTIPLY MREWE BY 1000, SO THAT RESULT IS IN MM WATER.
C MULTIPLY MRSN BY 100, SO THAT RESULT IS IN CM SNOW.
C
10 WETRAD=TSOL-(TSOL-TABSOR)+TATERM-TGER
DELQM=WETRAD+TDTERM+ITERM+GTERM+PTERM-DELQS
DELRWE=(DELQM/(LHEATF*DENW))*1000
DELRW=(DELQM/(LHEATF*(DENS*1000)))*100

```

MSNW-DELRNE  
MRSW-DELRN  
RETURN  
END

C

C -----

```
C
C SUBROUTINE RAINMP
C -----
C CALCULATES THE ENERGY INPUT TO THE PACK BY RAIN FALLING ON
C A MELTING PACK AT 0OC. THE EQUATION IS TAKEN FROM MALE &
C GRAY (1981). THE UNITS ARE MJm-2dy-1.
C
  SUBROUTINE RAINMP(I,N,PPTN,PTERM,DENW,K30)
  COMMON/RAIN/AIRTP
  REAL PTERM
  DATA LHEATF,BCAPSN,BCAPW/0.334,2.09,4.21/
  DATA SPHTW/4.18/
  PTERM=(DENW*SPHTW*AIRTP*PPTN)/1000
  PTERM=PTERM/1000
  K30=1
  RETURN
  END
C
C -----
```

```

C SUBROUTINE CSFRQ
C -----
C CALCULATES SFRQ, THE VERTICAL GRID SPACING IN EACH
C COMPUTATIONAL LAYER.
C
      SUBROUTINE CSFRQ(I,N)
      COMMON/MATRIX3/THKMK1(1,6),THKMK2(2,6)
      COMMON/VECTOR/VNEWSN(1,6),VOLDNS(1,6)
      COMMON/TSTM2/NOMATL,NIPTS
      COMMON/VEGI/IVEG,SIGF,STATE,EFF,FOLA,HFOL
      COMMON/SFRQ/SFRQ(6)
      REAL SFRQ1,SFRQ2
      DATA TOTIM,TFRQ,TFRNT/1,1.0,60.0/
C
C CALCULATION OF SFRQ FOR LAYER 1
C
      IF(NOMATL.EQ.1)THEN
      SFRQ1=(THKMK1(1,1))/2
      ELSE
      SFRQ1=(THKMK2(1,1))/2
      END IF
100  IF(SFRQ1.LE.5.0)THEN
      GOTO 200
      ELSE
      IF(SFRQ1.LE.10.0)THEN
      GOTO 200
      ELSE
      SFRQ1=SFRQ1/2
      GOTO 100
      END IF
      END IF
200  SFRQ(1)=SFRQ1
C
C CALCULATION OF SFRQ FOR LAYER 2, IF NECESSARY
C
      IF(NOMATL.EQ.2)THEN
      SFRQ2=THKMK2(2,1)/2
300  IF(SFRQ2.LE.5.0)THEN
      GOTO 400
      ELSE
      IF(SFRQ2.LE.10.0)THEN
      GOTO 400
      ELSE
      SFRQ2=SFRQ2/2
      GOTO 300
      END IF
      END IF
400  SFRQ(2)=SFRQ2
      END IF
C
C CALCULATION OF TIMESTEP ENSURING NUMERICAL STABILITY.
C

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```
IF(NOMATL.EQ.1)THEN
TIMSP1=0.5*(SFRQ(1)*SFRQ(1)/VNEWSN(1,2))
ELSE
TIMSP1=0.5*(SFRQ(1)*SFRQ(1)/VNEWSN(1,2))
TIMSP2=0.5*(SFRQ(2)*SFRQ(2)/VOLDNSN(1,2))
TIMSP1=MIN(TIMSP1,TIMSP2)
END IF
ITIME=INT(TIMSP1)
IF(ITIME.EQ.0)ITIME=1
IF(ITIME.GT.5)ITIME=5
IF(IVEG.EQ.1)ITIME=1
IFRQ=REAL(ITIME)
RETURN
END
```

C

C -----



```

C
C SUBROUTINE TSTM
C -----
C CALCULATES THE SHORTWAVE, LONGWAVE, LATENT HEAT AND SENSIBLE HEAT
C EXCHANGES OVER THE SNOWPACK OR SOIL SURFACE, AND THE HEAT TRANSPORT
C THROUGH THE SOIL OR SNOW. TSTM HAS BEEN CONVERTED INTO A SUBROUTINE
C FROM BALICK ET.AL. (1981a & b). THE CONVERSION OF TSTM AND INCLUSION
C OF VEGIE WAS AIDED BY DR. RANDY SCOGGINS (WES). VEGETATED SURFACES
C ARE MODELLED USING THE SUBMODEL VEGIE. TSTM WAS ORIGINALLY THE TERRAIN
C SURFACE TEMPERATURE MODEL AND ITS FUNCTION WAS TO PREDICT SURFACE
C TEMPERATURE.

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C
C
C

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      SUBROUTINE TSTM(I,AN1,AN,K10,AVSTP,AVGBR,AVSOL,AVABSR,
& AVATER,AVHTER,AVDTER,K2,AVBTTP,TGBR,TSOL,TABSOR,IATERM,
& THTERM,TDTERM)

```

```

C
C INITIALISATION, DECLARATION AND DATA STATEMENTS
C

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```

      INTEGER OUTCD
      DIMENSION DATPK(100,10)
      DIMENSION RHOC(6),MAX(10),DEPTH(450),FMM(30,10),BBB(30,10)
      DIMENSION TITLE(7)
      DIMENSION NK(6),ATP(2),FEB(2)
      DIMENSION RR(6),INTR(7)
      DIMENSION TRK(6),ALPH(6),FK(6),STOR(7,450),STABN(6)
      REAL KTEMPG,KTEMPA,LAT,ACL(8),BCL(8),M,KSQ,BOTTP,WET,
& ISOL,IGBR,IABSOR,IATERM,IHTERM,IDTERM,ISURFG,IREFRA,
& SLOPE,SURFAC,CLR(8)
      CHARACTER HEADER*72,AN*1,AN1*1
      COMMON/MATRX1/XXX(30,10),YYY(30,10)
      COMMON/MATRX2/DEPMK1(2,2),DEPMK2(3,2)
      COMMON/MATRX3/THPMK1(1,6),THPMK2(2,6)
      COMMON/TSTM1/PRESS,NCLOUD,ZA,SLOPE1,SURFC1,DAY,LAT
      COMMON/TSTM2/NOMATL,NIPTS
      COMMON/VEGI/IVEG,SIGF,STATE,EFF,ALBEDO,HPOL
      COMMON/SFRQ/SFRQ(6)
      DATA TOTIM,TFRQ,TFRNT/1,1,0,60,0/
      DATA CLR/0.04,0.08,0.17,0.20,0.22,0.24,0.24,0.25/
      DATA OUTCD/0/
      DATA ACL/82.2,87.1,52.5,39.0,34.7,23.8,11.2,15.4/
      DATA BCL/.079,.148,.112,.063,.104,.159,-.167,.028/
      DATA SIGMA,PI,AC,BC/8.12E-11,3.141593,17.269,35.86/
      DATA CC/0.281/
      DATA LAST,G,KSQ,CP/2,980.0,0.18,0.24/

```

```

C
C STATEMENT FUNCTIONS FOR USE IN VEGETATION SECTION
C

```

```

      E(T)=RH*6.108*EXP(AC*(T-273.15)/(T-BC))
      ESAT(T)=6.108*EXP(AC*(T-273.15)/(T-BC))
      Q(T)=0.622/(PRESS/E(T)-.378)

```

QSAT(T)=0.622/(PRESS/ESAT(T)-.378)

C

C CONVERSION OF VARIABLES PASSED FROM MAIN PROGRAM INTO FORM  
C USED IN TSTM. 1 OR 2-LAYERED SNOWPACK USED.

C

```

IFLAG2=0
IRETRN=0
IFRNT=0
SUN=0.0
IF(NOMATL.EQ.1)THEN
  XCK(1,5)=DEPMK1(1,1)
  YYY(1,5)=DEPMK1(1,2)
  XCK(2,5)=DEPMK1(2,1)
  YYY(2,5)=DEPMK1(2,2)
  THK(1)=THQMK1(1,1)
  ALPH(1)=THQMK1(1,2)
  FK(1)=THQMK1(1,3)
  EPSN=THQMK1(1,4)
  SMALLA=(1-THQMK1(1,5))
ELSE
  XCK(1,5)=DEPMK2(1,1)
  YYY(1,5)=DEPMK2(1,2)
  XCK(2,5)=DEPMK2(2,1)
  YYY(2,5)=DEPMK2(2,2)
  XCK(3,5)=DEPMK2(3,1)
  YYY(3,5)=DEPMK2(3,2)
  THK(1)=THQMK2(1,1)
  THK(2)=THQMK2(2,1)
  ALPH(1)=THQMK2(1,2)
  ALPH(2)=THQMK2(2,2)
  FK(1)=THQMK2(1,3)
  FK(2)=THQMK2(2,3)
  EPSN=THQMK2(1,4)
  SMALLA=(1-THQMK2(1,5))
END IF

```

C-----

C INITIALIZE-VARIABLES-AND-CONSTANTS

99996 ASSIGN 99994 TO I99995

GO TO 99995

99994 CONTINUE

C-----

C INPUT-DATA

ASSIGN 99989 TO I99990

GO TO 99990

C-----

C PRINT-INPUT-DATA

99989 ASSIGN 99987 TO I99988

IF(AM1.EQ.'Y')GO TO 99988

99987 CONTINUE

C-----

C CALCULATE-TABLE-SLOPE-AND-INTERCEPT

99986 ASSIGN 99982 TO I99983

GO TO 99983

-----

C CALCULATE-SURFACE-AND-LAYER-TEMPERATURE

99982 CONTINUE

ASSIGN 99980 TO I99981

GO TO 99981

-----

99980 CONTINUE

PPTH=(YYY(1,7)+YYY(2,7))/2

C

C CALCULATION OF DAILY TOTALS FOR THE ENERGY-BUDGET VARIABLES

C REQUIRED BY THE MAIN PROGRAM.

C

SUMC2=0

SUMC3=0

SUMC4=0

SUMC5=0

SUMC6=0

SUMC7=0

SUMC8=0

SUMC9=0

DO 99 I=1,K10

SUMC2=SUMC2+DATPK(I,2)

SUMC3=SUMC3+DATPK(I,3)

SUMC4=SUMC4+DATPK(I,4)

SUMC5=SUMC5+DATPK(I,5)

SUMC6=SUMC6+DATPK(I,6)

SUMC7=SUMC7+DATPK(I,7)

SUMC8=SUMC8+DATPK(I,8)

SUMC9=SUMC9+DATPK(I,9)

99 CONTINUE

C

C CONVERT DAILY ENERGY TOTALS IN  $\text{lyhr}^{-1}$  TO  $\text{MJm}^{-2}\text{day}^{-1}$

C

TGER=SUMC3/24

TSOL=SUMC4/24

TABSOR=SUMC5/24

TATERM=SUMC6/24

TETERM=SUMC7/24

TDTERM=SUMC8/24

C

C CALCULATION OF MEAN DAILY ENERGY VALUES IN  $\text{MJm}^{-2}$

C AND MEAN SURFACE AND BASAL TEMPERATURES ( $^{\circ}\text{C}$ ).

C

AVSTP=SUMC2/K10

AVGER=(SUMC3/K10)/24

AVBCL=(SUMC4/K10)/24

AVABSR=(SUMC5/K10)/24

AVATER=(SUMC6/K10)/24

AVETER=(SUMC7/K10)/24

AVDTER=(SUMC8/K10)/24

AVBTTP=SUMC9/K10

```

C
C RETURN TO MAIN PROGRAM
C
      WRITE(*,*)'NORMAL TERMINATION'
C-----
C      STOP
      RETURN
C-----
C-----
99997 CONTINUE
C FORMATS
90   FORMAT(' BOTTOM BOUNDRY INDEX=',I3)
92   FORMAT(' BOTTOM BOUNDRY TEMPERATURE=',F6.1,' DEG C')
95   FORMAT(' BOTTOM BOUNDRY HEAT FLUX=',F6.1,'W/M**2')
97   FORMAT(F11.2,F11.1,F13.2,F13.1,F8.2)
120  FORMAT(A8,F8.1)
140  FORMAT(F5.1,F10.1,F6.1,F12.1,F12.1,F13.1)
145  FORMAT(F6.1,F7.1)
150  FORMAT(F12.1,I12,F11.2)
160  FORMAT(F11.2,F13.2,F8.1,F10.1)
170  FORMAT(F9.4,F12.1)
180  FORMAT(I7,F16.1,F11.0,F12.0)
C190 FORMAT(4X,F5.2,F6.1,2X,I8,I9,I11,I9,I9,I8)
190  FORMAT(4X,F5.2,F6.1,F8.2,F8.2,F8.2,F8.2,F8.2,F8.2)
260  FORMAT(6X,F8.1,F11.2,F9.2,F9.2,F8.2,F10.2,F8.2)
200  FORMAT(F6.2,F8.2)
210  FORMAT(I6,F11.1,F12.1,F14.2,F14.2)
220  FORMAT(1H1)
230  FORMAT(A72)
240  FORMAT(4X,F7.2,3X,F5.0,5X,F6.2,10X,F6.2,6X,F7.2)
250  FORMAT(6X,F6.1,13X,F4.1,12X,F5.1)
310  FORMAT(11X,'TOTAL GRAYBODY EFFECTIVE GROUND FOLIAGE',
      &      4X,'SOLAR')
320  FORMAT(14X,'RADIANCE TEMP',10X,'TEMP TEMP'
      &      ,4X,'INSOLATION')
330  FORMAT(5X,'HR',7X,'(LANGLEYS)',6X,'(C)',11X,'(C)'
      &      ,6X,'(C) (LANGLEYS)')
340  FORMAT(6X,'-----REFL-NREFL----REFL----NREFL',30(1H-))
270  FORMAT(3X,F5.2,F8.2,F8.2,2X,F8.2,F8.2,F8.2,F8.2,F8.2)
350  FORMAT(57X,'SENSIBLE LATENT')
360  FORMAT(5X,'HRS SURFACE GRAYBODY SOLAR SURFACE ATMOS',
      &      ' IR HEAT HEAT')
370  FORMAT(11X,'TEMP RADIANCE INSOLATION ABSORP EMISSION',
      &      ' LOSS FLUX')
380  FORMAT(11X,'DEG C',23(1H-),'(LANGLEYS)',24(1H-))
390  FORMAT(3X,'TIME',16X,'DEPTH, TEMPERATURE'/4X,'HR',21X,'CM',
      &      6X,'C'/2X,65(1H-))
400  FORMAT(2H0 ,F5.2,4(3X,F5.1,' ',F5.2))
410  FORMAT(10X,F5.1,1X,F5.2,3X,F5.1,1X,F5.2,3X,F5.1,1X,F5.2,
      &      3X,F5.1,1X,F5.2)
      GO TO 199997
C-----

```

```
99995 CONTINUE
C   TO INITIALIZE-VARIABLES-AND-CONSTANTS
      BB=-2.4E-4
      MAX(1)=2
      MAX(2)=2
      MAX(3)=2
      MAX(4)=2
      MAX(5)=NIPTS
      MAX(6)=2
      MAX(7)=2
      MAX(8)=0
      MAX(9)=0
      MAX(10)=3
      IBUG=0
      IBOF=0
      GO TO 199995
```

```
C-----
99990 CONTINUE
C   TO INPUT-DATA
C
C   INPUT-ATMOSPHERIC-SPECIFICATIONS
      ASSIGN 99978 TO 199979
      GO TO 99979
C
C   INPUT-SURFACE-ORIENTATION-SPECIFICATIONS
99978 ASSIGN 99976 TO 199977
      GO TO 99977
C
C   INPUT-HEAT-FLOW-CALCULATION-CONTROLS
99976 ASSIGN 99974 TO 199975
      GO TO 99975
C
C   INPUT-INITIAL-TEMPERATURE-PROFILE
99974 ASSIGN 99972 TO 199973
      GO TO 99973
C
C   INPUT-TOP-SURFACE-CONSTANTS
99972 ASSIGN 99970 TO 199971
      GO TO 99971
C
C   INPUT-LAYER-SPECIFICATIONS
99970 ASSIGN 99968 TO 199969
      GO TO 99969
C
C   INPUT-BOTTOM-BOUNDARY-DATA
99968 ASSIGN 99966 TO 199967
      GO TO 99967
C
C   INPUT-VEGETATION-PARAMETERS
99966 ASSIGN 99798 TO 199799
      GO TO 99799
C
```

99798 GO TO 199990

C-----

99879 CONTINUE

C TO INPUT-ATMOSPHERIC-SPECIFICATIONS

C

C LINE TIME AIR TEMP RH CLOUD COVER WIND SPEED, INSOLATION  
C NO. HR DEG C I (0-1) M/3 CAL/CM\*\*2-MIN

C

XXX(2,1)=XXX(2,1)+2400\*(XXX(2,8)-XXX(1,8))

860 DO 99865 J=1,2

IXXX=INT(XXX(J,1)/100.0)\*100

AXXX=(XXX(J,1) - REAL(IXXX))/60.0

XXX(J,1)=REAL(IXXX)/100.0+AXXX

XXX(J,7)=XXX(J,1)

XXX(J,2)=XXX(J,1)

XXX(J,3)=XXX(J,1)

XXX(J,4)=XXX(J,1)

XXX(J,6)=XXX(J,1)

YYY(J,1)=YYY(J,1)+273.1

YYY(J,9)=YYY(J,9)+273.15

YYY(J,2)=YYY(J,2)\*0.01

YYY(J,6)=YYY(J,6)\*100.0

YYY(J,4)=YYY(J,4)/697.6

99865 CONTINUE

XXX(3,10)=XXX(2,1)

XXX(2,10)=14.0

XXX(1,10)=XXX(1,1)

YYY(3,10)=YYY(2,1)

YYY(2,10)=YYY(1,9)

YYY(1,10)=YYY(1,1)

C

840 FACTH=(1000.0/PRESS)\*\*0.286

GO TO 199879

C-----

99877 CONTINUE

C TO INPUT-SURFACE-ORIENTATION-SPECIFICATIONS

C

C LINE SFC SLOPE SFC AZIMUTH DAY LATITUDE  
C NO. DEG-HORIZ=0 DEG S=0 JULIAN DEG

C

SLOPE=SLOPE1

SURFAC=SURFC1

SLOPE=SLOPE\*PI/180.0

SURFAC=SURFAC\*PI/180.

GO TO 199877

C-----

99875 CONTINUE

C TO INPUT-HEAT-FLOW-CALCULATION-CONTROLS

C

C LINE NO. OF NO. OF 24 HRS TIME STEP PRINT FREQ  
C NO. LAYERS REPITIONS MIN MIN

C

1-6 2-5

```

C
      TOTIM=XXX(2,1) - XXX(1,1)
      GO TO I99975
C-----
99973 CONTINUE
C   TO INPUT-INITIAL-TEMPERATURE-PROFILE
C
C     LINE NO. OF
C     NO. PROFILE POINTS
C
C     LINE DEPTH TEMP
C     NO. CM   DEG C
C
      MAX(5)=NIPTS
      DO 99964 J3=1,NIPTS
      YYY(J3,5)=YYY(J3,5)+273.15
99964 CONTINUE
      GO TO I99973
C-----
99971 CONTINUE
C   TO INPUT-TOP-SURFACE-CONSTANTS
C     LINE EMISSIVITY ABSORBTIVITY MOISTURE
C     NO.                               CONTENT DRY WT.
C
      FACTA=SIGMA*EPSN
C
      GO TO I99971
C-----
99967 CONTINUE
C   TO INPUT-BOTTOM-BOUNDARY-DATA
C
C     IF LFLUXY=0, THERE IS NO HEAT FLUX THROUGH BOTTOM
C     IF IFLUXY LT 0, THERE IS NO AIRSPACE BENEATH BOTTOM
C     IF IFLUXY GT 0, THERE IS AIRSPACE BENEATH BOTTOM
C
      LFLUXY=-1
      IF(.NOT.(LFLUXY.EQ.0)) GO TO 99962
      DFRM0=YYY(NIPTS,5)
      TB=0.
      GO TO 99963
99962 IF(.NOT.(LFLUXY.LT.0)) GO TO 99961
C
      DFRM1=-0.5
      TB=FK(NCMATL)
      REP=0.0
      EK=0.
      REP=0.
      TR=0.0
      FACTD=0.
      FACTE=0.
      EK=0.

```

```

DFRM1-DFRM1/697.6
GO TO 99963
99961 CONTINUE
99963 GO TO I99967
C-----
99969 CONTINUE
C TO INPUT-LAYER-SPECIFICATIONS
C
C LINE THICKNESS VERT. GRID THERMAL DIFF HEAT COND
C NO. CM SPACE-CM CM**2/MIN CAL/MIN-CM-K
C
DO 99960 J4=1,NOMATL
RROC(J4)=FK(J4)/ALPH(J4)
99960 CONTINUE
C CONTROL SWITCHES SPECIFIED
C
NIT=1
IEFSWT=1
GO TO I99969
C-----
99799 CONTINUE
C TO INPUT-VEGETATION-PARAMETERS
C IVEG DETERMINES WHETHER VEGETATION PARAMETERS ARE USED
C OR NOT. HEIGHT OF THE METEOROLOGICAL INSTRUMENTS FROM
C WHICH THE DAILY DATA ARE TAKEN ARE ASSUMED TO BE 100CM
C ABOVE THE FOLIAGE HEIGHT, SEE TEXT FOR FULLER EXPLANATION.
C
IF(IVEG.EQ.0) GO TO 1120
POLA=1-ALBEDO
IF(HPOL.GE.ZA)THEN
ZA=HPOL+100.0
END IF
IF(SIGF.LE.0.0)GO TO I99799
TF=YYY(1,1)
IVEG=1
EP1=EPF+EPSN-EPF*EPSN
ZO=0.131*HPOL**0.997
CH0=KSQ/(ALOG(ZA/ZO)**2)
ZDSP=0.701*HPOL**0.979
CHR=KSQ/(ALOG((ZA-ZDSP)/ZO)**2)
CBG=(1.-SIGF)*CH0+SIGF*CHR
DELTMP=1.
QAP=QSAT(TF)
1120 GO TO I99799
C-----
99988 CONTINUE
C TO PRINT-INPUT-DATA
C WRITE(*,139)
WRITE(*,220)
WRITE(*,*)' '
WRITE(*,230)HEADER
WRITE(*,*)' '

```



```

WRITE(*,*)' ATMOSPHERIC-SPECIFICATIONS'
WRITE(*,*)' '
WRITE(*,*)' ATMOS PRESS CLOUD TYPE SHELTER'
WRITE(*,*)' MB INDEX HEIGHT-CM'
WRITE(*,150)PRESS,NCLOUD,ZA
WRITE(*,*)' '
WRITE(*,*)' TIME AIR TEMP RH CLOUD COVER WIND SPEED'
& , ' SOLAR IRRAD'
WRITE(*,*)' HRS DEG C X (0-1) M/S W/M**2'
MMAX=2
WRITE(*,140)(XXX(J,1),YYY(J,1)-273.15,
& YYY(J,2)*100.0,YYY(J,3),YYY(J,6)*0.01,YYY(J,4)*697.6,J=1,MMAX)
WRITE(*,*)' '
WRITE(*,*)' SURFACE-ORIENTATION-SPECIFICATIONS'
WRITE(*,*)' '
WRITE(*,*)' SFC SLOPE SFC AZIMUTH DAY LATITUDE'
WRITE(*,*)' DEG-HORIZ=0 DEG S=0 JULIAN DEG'
WRITE(*,180)SLOPE*180/PI,SURFAC*180.0/PI,DAY,LAT
WRITE(*,220)
WRITE(*,*)' HEAT-FLOW-CALCULATION-CONTROLS'
WRITE(*,*)' '
WRITE(*,*)' NO. OF NO. OF 24 HRS TIME STEP PRINT FREQ'
WRITE(*,*)' LAYERS REPETITIONS MIN MIN'
WRITE(*,*)' 1-6'
WRITE(*,180)NOMATL,TOTTIM/24.0,TFRQ,TPRNT
WRITE(*,*)' '
WRITE(*,*)' INITIAL-TEMPERATURE-PROFILE'
WRITE(*,*)' '
WRITE(*,145)(XXX(J,5),YYY(J,5)-273.15,
& J=1,NIPTS)
WRITE(*,*)' '
WRITE(*,*)' TOP-SURFACE-CONSTANTS'
WRITE(*,*)' '
WRITE(*,*)' EMISS ALBEDO '
WRITE(*,200)EPSN,SMALLA
WRITE(*,*)' '
WRITE(*,*)' INPUT-LAYER-SPECIFICATIONS'
WRITE(*,*)' LAYER THICKNESS VERT. GRID THERMAL DIFF HEAT COND'
WRITE(*,*)' NO. CM SPACE-CM CM**2/MIN'
& , ' CAL/MIN-CM-K'
DO 99956 J4=1,NOMATL
WRITE(*,210)J4,TEK(J4),SFRQ(J4),
& ALPH(J4),FK(J4)
99956 CONTINUE
WRITE(*,*)' '
WRITE(*,*)' INPUT BOTTOM BOUNDARY DATA'
WRITE(*,*)' '
IF(.NOT.(LFLUXY.EQ.0)) GO TO 99956
WRITE(*,90)LFLUXY
WRITE(*,92)DP990-273.15
WRITE(*,*)' '
WRITE(*,*)' '

```

```

      GO TO 99959
99958 IF(.NOT.(LFLUXY.LT.0)) GO TO 99957
      WRITE(*,90)LFLUXY
      WRITE(*,95)DFPM1*697.6
      WRITE(*,*)' '
      GO TO 99959
99957 WRITE(*,90)LFLUXY
      WRITE(*,95)DFPM1*697.6
      WRITE(*,*)'---BOTTOM SURFACE----- SURFACE BENEATH AIRSPACE TEMP'
      WRITE(*,*)'EMISSIVITY GEOM SHAPE EMISSIVITY GEOM SHAPE DEG C'
      WRITE(*,*)'          FACT(0.-1.)          FACT(0.-1.)'
      WRITE(*,97)REP,BK,REP,RK,TR-273.15
      WRITE(*,*)' '
99959 WRITE(*,*)' '
      IF(IVEG.EQ.0) GO TO I99988
      WRITE(*,*)' VEGETATION PARAMETERS'
      WRITE(*,*)' '
      WRITE(*,*)' COVERAGE STATE EMISSIVITY ALBEDO
& FOLIAGE HEIGHT'
      WRITE(*,*)' (0.0 -1.0)          (0.0 -1.0)          (0.0-1.0)
& (CM)'
      WRITE(*,240)SIGF,STATE,EFF,FOLA,HFOL
      WRITE(*,*)' '
      WRITE(*,*)' '
      WRITE(*,*)' '
      GO TO I99988
-----
C-----
99985 CONTINUE
C TO CALCULATE-INSOLATION-ON-SLOPE-SURFACE
C
C
C SOLVE-SOLAR-ZENITH
  ASSIGN 99951 TO I99952
  GO TO 99952
C
C SOLVE-SOLAR-AZIMUTH
99951 ASSIGN 99949 TO I99950
  GO TO 99950
C
C CALCULATE-SLOPE-ATMOS-ATTEN-AND-CLOUD-ADJUSTMENTS
99949 ASSIGN 99947 TO I99948
  GO TO 99948
C
99947 CONTINUE
C
99953 GO TO I99985
-----
99955 CONTINUE
C TO ZERO-VARIABLES
C
  I=0
  GO TO I99955

```

```

C-----
99952 CONTINUE
C   TO SOLVE-SOLAR-ZENITH
C
      TIME=AMOD(TIME,24.0)
      T0=2.0*PI*(DAY-1.0)/365.0
      DECL=0.006918-0.399912*COS(T0)+0.070257*SIN(T0)
&      -0.006758*COS(2.0*T0)+0.000907*SIN(2.0*T0)
&      -0.002697*COS(3.0*T0)+0.001480*SIN(3.0*T0)
      ELF=(LAT/180*PI)
      TIMER=(TIME/12*PI)+PI
      IF(TIMER.GT.2.*PI)TIMER=TIMER-2.*PI
      AA=COS(DECL)*COS(ELF)*COS(TIMER)
      BB=SIN(DECL)*SIN(ELF)
      C=AA+BB
      Z=ACOS(C)
      GO TO 199952

C-----
99950 CONTINUE
C   TO SOLVE-SOLAR-AZIMUTH
C
      XNUM=-COS(DECL)*SIN(TIMER)
      XDNUM=COS(ELF)*SIN(DECL)-SIN(ELF)*COS(TIMER)
      SAZ=ATAN(XNUM/XDNUM)
      IF(.NOT.(XNUM.LT.0.0.AND.XDNUM.GT.0.0)) GO TO 99944
      SAZ=SAZ+PI
      GO TO 99945
99944 IF(.NOT.(XNUM.GT.0.0.AND.XDNUM.GT.0.0)) GO TO 99943
      SAZ=SAZ-PI
99943 CONTINUE
99945 GO TO 199950

C-----
99948 CONTINUE
C   TO CALCULATE-SLOPE-ATMOS-ATTEN-AND-CLOUD-ADJUSTMENTS
C
      SICF=COS(Z)*COS(SLOPE)+SIN(Z)*SIN(SLOPE)
&      *COS(SAZ-SURFAC)
      IF(.NOT.(SICF.LT.0.0.OR.COS(Z).LE.0.0)) GO TO 99941
      SUB=0.0
      GO TO 99942
99941 M=1/COS(Z)
      IF(.NOT.(M.GE.0.0)) GO TO 99939
      TAL=0.02023
      IF(DAY.GE.92.0 .AND. DAY.LE.152.0)TAL=-0.02290
      TD=5352.2/(21.4-ALOG(RH*ESAT(TA)))
      WATER=EXP(0.07074*(TD-273.15)+TAL)
      AB=0.271*(WATER*M)**0.303
      A0=0.085-0.247*ALOG10(PRESS/1000.*1./M)
      ARG1=((1.-AB)*0.349+(1.-A0)/(1.-A0*0.2))*0.851
      GO TO 99940
99939 ARG1=1.0
99940 QP=2.0*ARG1

```

```

      QO=QP*SICF
      IF(.NOT.(NCLLOUD.EQ.0)) GO TO 99937
      SUN=QO
      GO TO 99936
99937 CONTINUE
      ARG2=- (BCL(NCLLOUD)-.059)*M
      CTF=(ACL(NCLLOUD)/94.4)*EXP(ARG2)
      SUN=QO-((CLOUD*CLLOUD)*(QO-QO*CTF))
99938 CONTINUE
99942 CONTINUE
      GO TO I99948
C-----
99983 CONTINUE
C   TO CALCULATE-TABLE-SLOPE-AND-INTERCEPT
      I=1
      GO TO 99935
99936 IF(I.GT.10) GO TO 99934
99935 IMAX=MAX(I)
      IF(IMAX.EQ.0)GO TO 99931
      J=1
      GO TO 99932
99933 IF(J.EQ.IMAX) GO TO 99931
99932 FMM(J,I)=(YYY(J+1,I)-YYY(J,I))/(XXX(J+1,I)-XXX(J,I))
      BBB(J,I)=YYY(J,I)-FMM(J,I)*XXX(J,I)
      J=J+1
      GO TO 99933
99931 I=I+1
      GO TO 99936
99934 GO TO I99983
C-----
99930 CONTINUE
C   TO GET-TABLE-VALUES
C
      IMAX=MAX(NTABL)
      IJ=1
      IF(.NOT.(XN.GE.XXX(IMAX,NTABL))) GO TO 99928
      YW=YYY(IMAX,NTABL)
      GO TO 99929
99928 IF(IJ.EQ.IMAX+1) GO TO 99927
      JJ=IJ
      IF(.NOT.(XXX(IJ,NTABL).LT.XN)) GO TO 99925
      IJ=IJ+1
      GO TO 99928
99925 IF(.NOT.(XXX(IJ,NTABL).EQ.XN)) GO TO 99924
      YW=YYY(IJ,NTABL)
      IJ=IMAX+1
      GO TO 99928
99924 IF(.NOT.(XXX(IJ,NTABL).GT.XN)) GO TO 99923
      JJ=JJ-1
      YW=FMM(IJ,NTABL)*XN+BBB(IJ,NTABL)
      IJ=IMAX+1
99923 CONTINUE

```

```

          GO TO 99928
99927 CONTINUE
99929 GO TO I99930
C-----
99981 CONTINUE
C   TO CALCULATE-SURFACE-AND-LAYER-TEMPERATURE
C
C   SET-UP-INITIAL-CONDITIONS
      ASSIGN 99921 TO I99922
      GO TO 99922
C
C   PRINT-OUTPUT-HEADING
99921 ASSIGN 99919 TO I99920
      GO TO 99920
C
99919 CONTINUE
C
C   RUN-HEAT-FLOW-PROGRAM
      ASSIGN 99917 TO I99918
      GO TO 99918
C
C   SET-UP-AND-PRINT-OUTPUT
99917 ASSIGN 99915 TO I99916
      GO TO 99916
C
99915 IF(IRETRN.EQ.1) GO TO 4100
      GO TO 99919
4100 CONTINUE
      GO TO I99981
C-----
99922 CONTINUE
C   TO SET-UP-INITIAL-CONDITIONS
C
      PTIME=TOTTIM-24.0
      TIME=XXX(1,1)
      DIST=0.
      IFLAG=0
      IF (TFRQ.LE.0) TFRQ=TOTTIM
      DELT=TFRQ/60.
      ITIME=MAX1(TOTTIM/DELT+.9,1.1)
      IX=1
      IY=1
      GO TO 99913
99914 IF(IX.GT.NOMATL) GO TO 99912
99913 INTR(IX)=IY
      IF (SFRQ(IX).LE.0.) SFRQ(IX)=THK(IX)/10.
      NK(IX)=MAX1(THK(IX)/SFRQ(IX)+.9,1.1)
      RR(IX)=60.0*DELT/(SFRQ(IX)*SFRQ(IX))
C
C CALCULATION OF NUMERICAL STABILITY PARAMETER, TO
C ENSURE NUMERICAL STABILITY.
C

```

```

      STABN(IX)=ALPH(IX)*RR(IX)
      IF(STABN(IX).GT.0.5)THEN
      STABN(IX)=0.5
      END IF
C
      LAYERS=0
      GO TO 99910
99911 IF(LAYERS.GT.MX(IX)) GO TO 99909
99910 XN=DISI
      NTABL=5
      DEPTH(IY)=XN
C
C      GET-TABLE-VALUES
      ASSIGN 99908 TO I99930
      GO TO 99930
C
99908 TEMP=YN
      STOR(1,IY)=TEMP
      STOR(5,IY)=TEMP
      STOR(6,IY)=FK(IX)
      STOR(7,IY)=RBOC(IX)
      STOR(4,IY)=0.
      STOR(2,IY)=FK(IX)
      STOR(3,IY)=RBOC(IX)
      IY=IY+1
      DIST=DIST+SFRQ(IX)
      LAYERS=LAYERS+1
      GO TO 99911
99909 IX=IX+1
      DIST=DIST-SFRQ(IX-1)
      GO TO 99914
99912 JMAX=IY-1
      INTR(IX)=JMAX
      NFRNT=MAX1(TPRNT/TFRQ+.9,1.1)
      IFRNT=NFRNT
      GO TO I99922
C-----
99920 CONTINUE
C      TO PRINT-OUTPUT-HEADING
C
C      IF(OUTCD.EQ.1)GO TO 1610
C      IF(IVEG.GT.0) GO TO 1420
C      WRITE(*,350)
C      WRITE(*,360)
C      WRITE(*,370)
C      WRITE(*,380)
C      GO TO I99920
C1420 WRITE(*,310)
C      WRITE(*,320)
C      WRITE(*,330)
C      WRITE(*,340)
C      GO TO I99920

```

```

C1610 WRITE(*,390)
      GO TO 199820
C-----
99918 CONTINUE
C   TO RUN-HEAT-FLOW-PROGRAM
C
      IF(.NOT.(IFLAG2.EQ.0)) GO TO 99907
      ITER=IIT
      TIME=TIME+DELT
99907 ZZA=STOR(5,1)
      ZZB=STOR(5,JMAX)
      TEML=ZZA
      TEMR=ZZB
C
C
C   CALCULATE-BOUNDARY-CONDITIONS
C CALCULATE ENERGY-BUDGET TERMS WITH VEGETATION OR WITHOUT
C
      IF(IVEG.EQ.0)GO TO 930
      ASSIGN 99905 TO 199800
      GO TO 99800
930   ASSIGN 99905 TO 199906
      GO TO 99906
C
C   CALCULATE-UPPER-BOUNDARY-VALUES
C USING ENERGY-BUDGET, FIND TOP TEMPERATURE WITH VEGETATION
C OR WITHOUT.
C
99905 IF(IVEG.EQ.0) GO TO 900
      ASSIGN 99903 TO 199797
      GO TO 99797
900   ASSIGN 99903 TO 199904
      GO TO 99904
C
99903 IX=1
      J=2
      IMATL=NOMATL
      IF(.NOT.(NOMATL.EQ.1)) GO TO 99901
      IZ=IX(IX)-1
      IF(.NOT.(IZ.GT.0)) GO TO 99900
C
C   CALCULATE-INSIDE-MATERIAL-VALUES
      ASSIGN 99898 TO 199899
      GO TO 99899
C
99898 CONTINUE
99900 GO TO 99902
99901 GO TO 99896
99897 IF(IMATL.LT.1) GO TO 99895
99896 IF(.NOT.(IMATL.GT.1)) GO TO 99893
      IZ=IX(IX)-1
      IF(.NOT.(IZ.GT.0)) GO TO 99892

```

```

C
C   CALCULATE-INSIDE MATERIAL-VALUES
    ASSIGN 99891 TO 199899
    GO TO 99899

C
99891 CONTINUE

C
C   CALCULATE-INTERFACE-VALUES
99892 ASSIGN 99899 TO 199890
    GO TO 99890
99899 GO TO 99894
99893 IZ=IK(IX)-1
    IF(.NOT.(IZ.GT.0)) GO TO 99888

C
C   CALCULATE-INSIDE-MATERIAL-VALUES
    ASSIGN 99887 TO 199899

C
    GO TO 99899
99887 CONTINUE
99888 CONTINUE
99894 IMATL=IMATL-1
    GO TO 99897
99895 CONTINUE

C
C   CALCULATE-LOWER-BOUNDARY-VALUES
99902 ASSIGN 99883 TO 199886
    GO TO 99886

C
99883 GO TO 199918
C-----
99906 CONTINUE
C   TO CALCULATE-BOUNDARY-CONDITIONS
    B = -FK(1)
    T=TIME

C
C   CALCULATE-BOTTOM-BOUNDARY-HEAT-TERMS-APRM-DPRM-BPRM
    ASSIGN 99880 TO 199881
    GO TO 99881

C
C
C   ATMOSPHERIC-INFRARED-EMISSION-ATERM
99880 ASSIGN 99878 TO 199879
    GO TO 99879

C
99878 CONTINUE
C   CALCULATE-SOLAR-INSOLATION-FOR-DAY-AND-TIME
    DAY=XXX(1,8)
    ASSIGN 42 TO 199885
    GO TO 99885
42   BTERM=SUN
    IF(BTERM.GT.0)BTERM=BTERM*SMALLA

C

```



```
C      CALCULATE-CONVECTION-ETERM
      ASSIGN 99876 TO 199877
      GO TO 99877

C
C
C      CALCULATE-EVAPORATIVE-HEAT-LOSS-DTERM
99876  ASSIGN 99874 TO 199875
      GO TO 99875

C
99874  D = ATERM + BTERM - HTERM-DTERM
521    CONTINUE
      GO TO 199906

C-----
99881  CONTINUE
C      TO CALCULATE-BOTTOM-BOUNDARY-HEAT-TERMS-APRM-DPRM-BPRM
C
      BPRM=TB
      IF(.NOT.(TB.EQ.0.0)) GO TO 99872
      APRM=1.0
      DPRM=DPRM0
      GO TO 99873
99872  APRM=FACT2*TEMP*TEMP*TEMP
      DPRM=DPRM1
99873  GO TO 199881

C-----
99879  CONTINUE
C      TO ATMOSPHERIC-INFRARED-EMISSION-ATERM
      XN=TIME
      NTABL=2

C
C      GET-TABLE-VALUES
      ASSIGN 99867 TO 199930
      GO TO 99930

C
99867  RH=YN
      XN=TIME
      NTABL=10

C
C      GET-TABLE-VALUES
      ASSIGN 99866 TO 199930
      GO TO 99930

C
99866  IA=YN
      XN=TIME
      NTABL=3

C
C      GET-TABLE-VALUES
      ASSIGN 99865 TO 199930
      GO TO 99930

C
99865  CLOUD=YN
      TAK=TA
```

```

TAC=(TAK-273.15)
EA=6.108*RH*EXP((AC*TAC)/(TAK-BC))
ALPHI=(0.61+0.05*SQRT(EA))*(1.0+(CLR*(N-CLOUD)*(CLOUD**2)))
DOWNIR=0.6132E-10*TAK**4*ALPHI
ATER=DOWNIR
GO TO 199879

```

```

C-----
99877 CONTINUE
C   TO CALCULATE-CONVECTION-HTERM
C
    XN=TIME
    NTABL=6
C
C   GET-TABLE-VALUES
    ASSIGN 99862 TO 199930
    GO TO 99930
C
99862 SPEED=YN
    TAK=TA
    ZASH=ZA
    TSK=TEML
    RBOA=-0.001*0.348*PRESS/TAK
1200 THETAZ=TAK*FACTH
    THETAS=TSK*FACTH
    DTHETA=(THETAZ-THETAS)/ZASH
    DU=SPEED/ZASH
    THETAV=(THETAZ+THETAS)/2.0
    RI=G*DTHETA/(THETAV*DU**2)
    COE1=15.0
    COE2=1.175
    EX=.75
    IF(TSK.GT.TAK)GO TO 31
    IF(RI.GT.0.2)RI=.19999
    COE1=5.0
    COE2=1.0
    EX=2.0
31 HTER=RBOA*KSQ*ZASH**2*DU
    & *(COE2*(1.0-COE1*RI)**EX)
    HTER=HTER*CP*DTHETA
99864 GO TO 199877
C-----
99875 CONTINUE
C   TO CALCULATE-EVAPORATIVE-HEAT-LOSS-DTERM
C
    XN=TIME
    NTABL=2
C
C   GET-TABLE-VALUES
    ASSIGN 99859 TO 199930
    GO TO 99930
C
99859 RB=YN

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```

      XM=TIME
      NTABL=10
C
C   GET-TABLE-VALUES
      ASSIGN 99858 TO I99930
      GO TO 99930
C
99858  CTEMA=YM
      KTEMPA=CTEMA
      CTEMA=CTEMA-273.15
      KTEMPG=TEML
      ES=EXP((AC*(KTEMPG-273.15))/(KTEMPG-BC))*6.1071
      EA=EXP((AC*CTEMA)/(KTEMPA-BC))*6.1071*RH
      DG=0.622/PRESS*(EA-ES)*WET/ZA
      XL=597.3-0.566*(CTEMA+KTEMPG-273.15)/2.0
      DTERM=HTER*XL*DG
      GO TO 99861
99860  DTERM=0.0
99861  GO TO I99875
C-----
99904  CONTINUE
C   TO CALCULATE-UPPER-BOUNDARY-VALUES
      T1=STABN(1)*(STOR(1,3)-2.*STOR(1,2)+STOR(1,1))+STOR(1,2)
      III=0
830   III=III+1
      T2=STOR(5,1)**4*FACTA*SFRQ(1)+FK(1)*STOR(5,1)
      & -(FK(1)*T1+D*SFRQ(1))
      T2=T2/(4.*FACTA*SFRQ(1)*STOR(5,1)**3+FK(1)-SFRQ(1)*DDDT)
      STOR(5,1)=STOR(5,1)-T2
      TEML=STOR(5,1)
C
C   SURFACE TEMPERATURE (TEML, STOR(5,1)) NOT ALLOWED TO RISE
C   ABOVE 0°C IF MOST SNOW PRESENT. THE SNOWPACK IS SATURATED
C   AT 0°C AND UNSATURATED AT TEMPERATURES BELOW 0°C.
C
      IF(TEML.GE.273.15)THEN
        TEML=273.15
        WET=1.0
      ELSE
        WET=0.0
      END IF
      IF(STOR(5,1).GT.273.15)THEN
        STOR(5,1)=273.15
      END IF
C
      GTERM=-FK(1)*(STOR(5,1)-T1)/SFRQ(1)
      ASSIGN 825 TO I99877
      GO TO 99877
825   ASSIGN 810 TO I99875
      GO TO 99875
810   DNEW=ATEM+BTERM-HTERM-DTERM
      IF(ABS(T2).LT.0.005 .OR. III.GT.30)GO TO I99904

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      DDDT--(DNEW-D)/I2
      D=DNEW
      GO TO 830

C
C-----
99899 CONTINUE
C   TO CALCULATE-INSIDE-MATERIAL-VALUES
C
      GO TO 99856
99857 IF(IZ.LE.0) GO TO 99855
99856 CONTINUE
      STOR(5,J)=STOR(1,J)+STABN(IX)*(STOR(1,J-1)-2.*STOR(1,J)
& +STOR(1,J+1))
      J=J+1
      IZ=IZ-1
      GO TO 99857
99855 GO TO I99899
C-----
C   TO CALCULATE-INTERFACE-VALUES
C
99890 CONTINUE
      BCOEF=STOR(6,J-1)/SFRQ(IX)
      DCOEF=STOR(6,J+1)/SFRQ(IX+1)
      CCOEF=BCOEF+DCOEF
      ACOEF=BCOEF/(2.*STABN(IX))+DCOEF/(2.*STABN(IX+1))
      STOR(5,J)=STOR(1,J)+(BCOEF*STOR(1,J-1)-CCOEF*STOR(1,J)+DCOEF*
& STOR(1,J+2))/ACOEF
      STOR(5,J+1)=STOR(5,J)
      IX=IX+1
      J=J+2
      GO TO I99890
C-----
C   TO CALCULATE-LOWER-BOUNDARY-VALUES
99886 IF(LFLUXY.EQ.0) GO TO 880
      I=1
      R2=FACTD
870 CONTINUE
      R1=SIGMA*BEP*BK*STOR(5,J)**4
      G1=-FK(NOMATL)*(STOR(5,J)-STOR(1,J-1))/SFRQ(NOMATL)
      F2=4.0*SIGMA*BEP*BK*STOR(5,J)**3-FK(NOMATL)/SFRQ(NOMATL)
      F2= - (R2-R1+G1+DFRM)/F2
      STOR(5,J)=STOR(5,J) + F2
      I=I+1
      IF(ABS(F2).GT.0.01 .AND. I.LE.30) GO TO 870
880 IF(LFLUXY.EQ.0) STOR(5,J)=STOR(5,J)
      GO TO I99886
C-----
99916 CONTINUE
C   TO SET-UP-AND-MANIPULATE OUTPUT
C
      IFLAG2=0
      IRETRN=0

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```

        IF(ITER.LE.1) GO TO 1245
        ITER=ITER-1
        IF (IEFSWT.NE.0) GO TO 1328
        IF (IPRNT.LE.1) GO TO 1244
        IF (ITIME.GT.1) GO TO 1328
1244  CONTINUE
C
C      MANIPULATE OUTPUT
        ASSIGN 99846 TO I99847
        GO TO 99847
C
99846  GO TO 1328
1245  IF (ITIME.GT.1) GO TO 1269
C
C      MANIPULATE OUTPUT
        ASSIGN 99845 TO I99847
        GO TO 99847
C
99845  IRETRN=1
        GO TO 1335
1269  ITIME=ITIME-1
        IF (IPRNT.LE.1) GO TO 1279
        IPRNT=IPRNT-1
        GO TO 1303
1279  CONTINUE
C
C      MANIPULATE OUTPUT
        ASSIGN 99844 TO I99847
        GO TO 99847
C
99844  IPRNT=NPRNT
1303  J=1
        IZ=NOMATL
1306  IX=NX(IZ)+1
1311  STOR(1,J)=STOR(5,J)
        STOR(2,J)=STOR(6,J)
        STOR(3,J)=STOR(7,J)
        J=J+1
        IF (IX.LE.1) GO TO 1329
        IX=IX-1
        GO TO 1311
1329  IF(IZ.LE.1) GO TO 1335
        IZ = IZ-1
        GO TO 1306
1328  IFLAG2=1
1335  CONTINUE
        GO TO I99916
C-----
99847  CONTINUE
C OUTPUT MANIPULATION
C HOURLY ENERGY VALUES FOR BOTH UNVEGETATED AND UNVEGETATED SURFACES
C ARE CONVERTED INTO  $\text{lyhr}^{-1}$ . THE ENERGY VALUES, SURFACE AND BASAL

```

C TEMPERATURES AND CORRESPONDING HOUR OF THE DAY ARE PLACED IN A DATA  
C MATRIX, DATMK.

C  
 TPACK=1.0  
 IF(.NOT.(TIME.GT.PTIME)) GO TO 99843  
 DO 99842 JCK=1,NOMATL+1  
 IJ=INT(JCK)  
 TITLE(JCK)=(STOR(5,IJ)-273.15)  
 99842 CONTINUE  
 NDX=TIME  
 IF(NDX.EQ.0)NDX=1

C  
 C RESULTS CALCULATED IN  $\text{cal cm}^{-2} \text{min}^{-1}$  IE.  $\text{lymin}^{-1}$  AND  
 C CONVERTED TO  $\text{lyhr}^{-1}$  BY \*60. THE DAILY TOTAL IS THEN DIVIDED  
 C BY 24 (ELSEWHERE IN THE PROGRAM) TO HAVE ANSWER IN  $\text{MJm}^{-2} \text{day}^{-1}$ .  
 C  $\text{MJm}^{-2} \text{day}^{-1}$ . IS NOW THE MORE WIDELY USED UNIT AND THEREFORE IS  
 C USED.

C  
 SIP=TITLE(1)  
 BOTP=STOR(5,J)-273.15  
 K10=K10+1  
 IF(IVEG.EQ.1) GO TO 1110

C  
 C ENERGY VALUES FOR UNVEGETATED SURFACE, CONVERTED TO  $\text{lyhr}^{-1}$ .

C  
 IGR=(0.813E-10\*EPSN\*STOR(5,1)\*\*4)\*60  
 ISOL=(BTERM/SMALLA)\*60  
 IABSOR=(ISOL\*SMALLA)  
 IATERM=ATERM\*60  
 IINTERM=INTERM\*60  
 IDTERM=DTERM\*60

C  
 1110 CONTINUE  
 DATMK(K10,1)=TIME  
 DATMK(K10,2)=TITLE(1)

C  
 C CALCULATE VEGETATION RADIANCE VALUES IF VEGETATION MOELED

C  
 ASSIGN 1400 TO I1410  
 IF(IVEG.EQ.1) GO TO 1410  
 1400 CONTINUE

C  
 IF(IVEG.EQ.0)THEN  
 C\*\*\*\*\*  
 C OPTION 2-HOURLY VALUES FOR ENERGY-BUDGET VALUES.  
 C INSERT:  
 WRITE(9,100)AMOD(TIME,24.),TITLE(1),IGR,ISOL,IABSOR,  
 & IATERM,IINTERM,IDTERM  
 C\*\*\*\*\*

C  
 DATMK(K10,3)=IGR  
 DATMK(K10,4)=ISOL

```

      DATMX(K10,5)=IABSOR
      DATMX(K10,6)=IATERM
      DATMX(K10,7)=INTERM
      DATMX(K10,8)=IDTERM
      DATMX(K10,9)=BOTT
    ELSE
C*****
C OPTION 2- HOURLY VALUES FOR ENERGY-BUDGET VALUES.
C INSERT:
      WRITE(9,270)AMOD(TIME,24.), ISURFG+IREFRA, ISURFG,
      & TEFFR-273.15, TEFF-273.15, TEMPL-273.15, TF-273.15, ISOL, SG
C*****
C
      DATMX(K10,3)=GRNDGB*60
      DATMX(K10,4)=SG
      DATMX(K10,5)=IABSOR
      DATMX(K10,6)=RLD*60
      DATMX(K10,7)=ESG*60
      DATMX(K10,8)=ELG*XL1*60
      DATMX(K10,9)=BOTT
    END IF
99843 GO TO 199847
C-----
99800 CONTINUE
C TO CALCULATE-BOUNDARY-CONDITIONS-WITH-VEG
      T=TIME
      XN=TIME
      NTABL=6
C
C GET-TABLE-VALUES
      ASSIGN 860 TO 199930
      GO TO 99930
C
960 UA=YN
      XN=TIME
      NTABL=4
C
C ATMOSPHERIC-INFRARED-EMISSION-ATERM
      ASSIGN 860 TO 199879
      GO TO 99879
C
C CALCULATE INCOMING SOLAR RADIATION.
980 CONTINUE
      DAY=XXX(1,8)
      ASSIGN 43 TO 199985
      GO TO 99985
43 SOL=SUN
C
      IF(UA.LT.10.0)UA=10.0
      UAF=0.83*SIGF*UA*SQRT(CHE)+(1.-SIGF)*UA
      DELTMP=5.
      CF=0.01*(1.+30.0/UAF)

```

```

DU=(UA-UAF)/ZA
RS=1/(.05+.0021*(SOL*60))
RC=RS*STATE/(7.0*SIGF)
ATF(1)=TF
ASSIGN 1210 TO I950
GO TO 950
1210 CONTINUE
FEB(1)=FENB
NDEX=0
1240 TF=TF+DELTMP
NDEX=NDEX+1
ASSIGN 1220 TO I950
GO TO 950
1220 CONTINUE
IF(NDEX.EQ.3.AND.FENB.LT.0.0)THEN
FENB=FENB*(-1.0)
END IF
FEB(2)=FENB
IF(FEB(1)*FEB(2).LT.0.0) GO TO 1230
IF(NDEX.EQ.5)THEN
GOTO 1230
END IF
IF(ABS(FEB(2)).GT.ABS(FEB(1)))DELTMP=-5.
IF(NDEX.LT.100)GO TO 1240
WRITE(*,*)'POLIAGE ENERGY BUDGET HAS NOT CROSSED X-AXIS'
WRITE(*,*)'AFTER 100 SEARCH STEPS. CHECK INPUT DATA.'
STOP
1230 CONTINUE
NDEX1=0
ATF(2)=TF
1270 SLOPE2=(FEB(2)-FEB(1))/(ATF(2)-ATF(1))
BINT=FEB(1)-SLOPE2*ATF(1)
TFO=-BINT/SLOPE2
NDEX1=NDEX1+1
IF(ABS(TF-TFO).LE.0.01)GO TO 1260
IF(NDEX1.EQ.5)THEN
GOTO 1260
END IF
TF=TFO
ASSIGN 1250 TO I950
GO TO 950
1250 CONTINUE
IF(FENB*FEB(2).GT.0.0)IP=2
IF(FENB*FEB(1).GT.0.0)IP=1
ATF(IP)=TF
FEB(IP)=FENB
GO TO 1270
1260 GO TO I99800
C-----
C TO CALCULATE-UPPER-BOUNDARY-VALUES-FOR-POLIAGE
99797 CONTINUE
DELTMP=5.

```



```

      ATF(1)=TEML
      ASSIGN 1310 TO I1300
      GO TO 1300
1310  CONTINUE
      FEB(1)=FENB
      NDEX=0
1340  TEML=TEML+DELTMP
      NDEX=NDEX+1
      ASSIGN 1320 TO I1300
      GO TO 1300
1320  CONTINUE
      FEB(2)=FENB
      IF(FEB(1)*FEB(2).LT.0.0) GO TO 1330
      IF(NDEX.EQ.5)THEN
      GOTO 1330
      END IF
      IF(ABS(FEB(2)).GT.ABS(FEB(1)))DELTMP=-5.
      IF(NDEX.LT.100)GO TO 1340
      WRITE(*,*)'GROUND ENERGY BUDGET HAS NOT CROSSED X-AXIS'
      WRITE(*,*)'AFTER 100 SEARCH STEPS. CHECK INPUT DATA.'
      STOP
1330  CONTINUE
      NDEX1=0
      ATF(2)=TEML
1370  SLOPE2=(FEB(2)-FEB(1))/(ATF(2)-ATF(1))
      BINT=FEB(1)-SLOPE2*ATF(1)
      TFO=-BINT/SLOPE2
      NDEX1=NDEX1+1
      IF(ABS(TEML-TFO).LE.0.001)GO TO 1360
      IF(NDEX1.EQ.5)THEN
      GOTO 1360
      END IF
      TEML=TFO
      ASSIGN 1350 TO I1300
      GO TO 1300
1350  CONTINUE
      IF(FENB*FEB(2).GT.0.0)IP=2
      IF(FENB*FEB(1).GT.0.0)IP=1
      ATF(IP)=TEML
      FEB(IP)=FENB
      GO TO 1370
1360  STOR(5,1)=TEML
      IF(TEML.GE.273.15)THEN
      TEML=273.15
      END IF
      GO TO I99797

```

C-----

```

C   TO CALCULATE-ENERGY-BUDGET
950  TAP=(1.-SIGF)*TA+SIGF*(0.3*TA+0.6*TF+0.1*TEML)
      DTHETA=(TA-TF)*FACTH/ZA
      THETAV=(TA+TF)*FACTH/2.0
      RI=G*DTHETA/(THETAV*DU**2)

```

```

RHOAF=-0.001*.348*PRESS/((TF+TA)/2.)
COE1=15.
COE2=1.175
EX=.75
IF(RI.LE.0.)GO TO 1280
IF(RI.GT.0.2)RI=0.199
COE1=5
COE2=1.
EX=2.0
1280 CONTINUE
HTER=RHOAF*KSQ*ZA**2*DU
& *COE2*(1.-COE1*RI)**EX
HSF=HTER*CP*DTHETA*60.
XL=597.3-0.566*TAF
RA=(ALOG((ZA-ZDSP)/Z0)*COE2*((1.-COE1*RI)**EX))**2
& /(.16*UA)
RDP=RA/(RS+RA)
QF=RDP*QSAT(TF)+(1.-RDP)*QAF
QAF=(1.-SIGF)*Q(TA)+SIGF*(Q(TA)*0.3+QF*0.6+QG*0.1)
LF=-RHOAF*CP/0.66*(ESAT(TF)-E(TA))/(RA+RC)*60.
IF(EF.LT.0.0)EF=0.0
SHEW=FOLA*SOL
XLNG=EFF*ATERM
TG4=EFF*EPSN/EP1*SIGMA*TEML**4
TF4=(EP1+EPSN)/EP1*EFF*SIGMA*TF**4
FENB=SIGF*(SHEW+XLNG+TG4-TF4)-HSF-EF
GO TO I950
C-----
C TO CALCULATE-ENERGY-BUDGET-FOR-GROUND
1300 CONTINUE
T1=ALPH(1)*RR(1)*(STOR(1,3)-2.*STOR(1,2)+STOR(1,1))
& +STOR(1,2)
TF4=SIGMA*TF**4
TG4=SIGMA*TEML**4
QG=NET*QSAT(TEML)+(1.-WET)*QAF
RBOAG=0.001*.348*PRESS/TAF
XL1=597.3-0.566*(TAF+TEML-2.0*273.15)/2.
SG=(1.-SIGF)*SOL
RLU=(1.-SIGF)*(EPSN*TG4+(1.-EPSN)*ATERM)
& +SIGF*(EPSN*TG4+(1.-EPSN)*EFF*TF4)/EP1
RLD=(1.-SIGF)*ATERM+SIGF*(EFF*TF4+(1.-EFF)*EPSN*TG4)/EP1
HSG=RBOAG*CP*CHG*UAF*(TEML-TAF)*60.
ELG=RBOAG*CHG*UAF*(QG-QAF)*60.
FENB=SMALLA*SG-RLU+RLD-HSG-ELG*XL1+(T1-TEML)/SFRQ(1)*FK(1)
GO TO I1300
C-----
C TO CALCULATE-RADIANCE-VALUES
1410 CONTINUE
REFRAD=((1.-SIGF)*(1-EPSN)+SIGF*(1-EFF))*DOWNIP
FOLGB=EFF*0.8132E-10*TF**4
GRNDGB=EPSN*0.8132E-10*TEML**4
SURFGB=SIGF*FOLGB+(1.-SIGF)*GRNDGB

```

```
EEF=SIGF*EPF+(1.-SIGF)*EPSN
TEFF=(SURFGB/0.8132E-10)**.25
ISURFG=SURFGB*60
TEFFR=((SURFGB+REFRAD)/(0.8132E-10))**.25)
IREFRA=REFRAD*60
ISOL=SOL*60
SG=((1.0-SIGF)*SOL)*60
IABSOR=SMALLA*SG
GO TO I1410
```

C

---

END

```

C*****
C OPTION 3-MASS CONSERVATION ROUTINE
C
C FOR A 2-LAYER PACK
3001  DELRNS=(DELQM/(LHEATF*VNEWSN(1,6)*1000))*100
      IF(DELRNS.GT.0.0)THEN
        IF(DELRNS.GE.THQK2(1,1))THEN
          ABC=DELRNS-THQK2(1,1)
          DFG=THQK2(1,1)
          THQK2(1,1)=0.0
          DELQM=(ABC*LHEATF*(VNEWSN(1,6)*1000))/100
          DELROS=(DELQM/(LHEATF*(VOLDSN(1,6)*1000))*100
            IF(DELROS.GE.THQK2(2,1))THEN
              GOTO 5002
            ELSE
              THQK2(2,1)=THQK2(2,1)-DELROS
              DEPTH=THQK2(2,1)
              NOMAIL=1
              NIPTS=2
              DO 800 J=1,6
                THQK1( J)=VOLDSN(1,J)
800    CONTINUE
              THQK1(1,1)=DEPTH
              DEPMK1(1,2)=AVSTP
              DEPMK1(2,2)=AVBOTTP
              DEPMK1(2,1)=DEPTH
              GOTO 5000
            END IF
          ELSE
            THQK2(1,1)=THQK2(1,1)-DELRNS
            DEPMK2(1,2)=AVSTP
            DEPMK2(3,2)=AVBOTTP
            DEPMK2(3,1)=DEPTH
            DEPMK2(2,1)=THQK2(1,1)
            DEPMK2(2,2)=((DEPMK2(2,1)/DEPTH)*(AVBOTTP-AVSTP))+AVSTP
            GOTO 5000
          END IF
        ELSE
          GOTO 5000
        END IF
      END IF
C
C FOR A 1-LAYER PACK
4000  IF(THQK1(1,6).EQ.VNEWSN(1,6))THEN
      DELRNS=(DELQM/(LHEATF*(VNEWSN(1,6)*1000))*100
        IF(DELRNS.GT.0.0)THEN
          IF(DELRNS.GE.THQK1(1,1))THEN
            GOTO 5002
          ELSE
            THQK1(1,1)=THQK1(1,1)-DELRNS
            DEPTH=THQK1(1,1)
            DEPMK1(1,2)=AVSTP
            DEPMK1(2,2)=AVBOTTP
          END IF
        END IF
      END IF

```

```

        DEPMK1(2,1)=THQMK1(1,1)
        GOTO 5000
    END IF
ELSE
    GOTO 5000
END IF
ELSE
DELR0S=(DELQM/(LHEATF*(VOLD5N(1,6)*1000)))*100
    IF(DELR0S.GT.0.0)THEN
        IF(DELR0S.GE.THQMK1(1,1))THEN
            GOTO 5002
        ELSE
            THQMK1(1,1)=THQMK1(1,1)-DELR0S
            DEPTH=THQMK1(1,1)
            DEPMK1(1,2)=AVSTP
            DEPMK1(2,2)=AVBOTTP
            DEPMK1(2,1)=THQMK1(1,1)
            GOTO 5000
        END IF
    ELSE
        GOTO 5000
    END IF
END IF

C
5000  IF(NOMATL.EQ.2.AND.THQMK2(1,1).LT.1.0)THEN
        DEPTH=THQMK2(1,1)+THQMK2(2,1)
        NOMATL=1
        NIPTS=2
        DO 450 J=1,6
            THQMK1(1,J)=VOLD5N(1,J)
450   CONTINUE
        THQMK1(1,1)=DEPTH
        DEPMK1(2,1)=DEPTH
        DEPMK1(1,2)=AVSTP
        DEPMK1(2,2)=AVBOTTP
        END IF

C
        MRSN=DFG+DELR0S
        WENS=DFG*VNEWSN(1,6)
        WEOS=DELR0S*VOLD5N(1,6)
        MRWE=WENS+WEOS
        IF(MRSN.LT.0.0)THEN
            MRSN=0.0
        END IF
        IF(MRWE.LT.0.0)THEN
            MRWE=0.0
        END IF
C*****

```

## VARIABLE DEFINITIONS: SNOMO

## (1) MAIN PROGRAM

AIRTP Air temperature, °C.

AVABSR Mean daily shortwave radiation absorbed at the surface,  $\text{MJm}^{-2}\text{day}^{-1}$ .

AVATER Mean daily shortwave radiation absorbed at the surface,  $\text{MJm}^{-2}\text{day}^{-1}$ .

AVBTTP Mean daily temperature at the base of the snowpack, °C.

AVDTER Mean daily evaporative heat flux,  $\text{MJm}^{-2}\text{day}^{-1}$ .

AVGBR Mean daily reflected longwave radiation,  $\text{MJm}^{-2}\text{day}^{-1}$ .

AVETER Mean daily sensible heat flux,  $\text{MJm}^{-2}\text{day}^{-1}$ .

AVSOL Mean daily incoming shortwave radiation,  $\text{MJm}^{-2}\text{day}^{-1}$ .

AVSTP Mean snow temperature, °C.

BOTTP Temperature at the base of the snowpack, °C.

CELL Identification number of the computational cell being modelled.

CRITDP Critical snowdepth, 5cm.

DATMX Matrix holding TSTM output values for manipulation.

DAY Julian date of day being modelled.

DAY1 Julian date of SNOMO initiation.

DDATE Julian date of day being modelled.

DELQS  $\Delta Q_s$ , snowpack internal energy change,  $\text{MJm}^{-2}\text{day}^{-1}$ .

DENSN Density of snow,  $\text{gcm}^{-3}$ .

DENW Density of water,  $\text{gcm}^{-3}$ .

DEPM1 Depth matrix for a 1-layer pack.

DEPM2 Depth matrix for a 2-layer pack.

DEPTH Snowpack depth, cm.

DEPTH1 Used in calculation of depth when converting 'new snow' to 'old snow'.

DUOT  $dU/dt$ , part of the snowpack energy-budget equation (equivalent to  $\Delta Q_s$ ), redundant.

ENAVM Energy available for melt,  $\Delta Q_m$ , calculated using energy totals,  $\text{MJm}^{-2}\text{day}^{-1}$ .

GTERM Ground heat flux,  $\text{calcm}^{-2}\text{min}^{-1}$ .

BCAPSN Heat capacity of snow,  $\text{kJkg}^{-1}\text{C}^{-1}$ .

BCAPW Heat capacity of water,  $\text{kJkg}^{-1}\text{C}^{-1}$ .

ILAPSE Determines which elevation data file is used to modify the air temperatures with lapse rate.

IRAIN Indicates occurrence of rain-on-snow. If irain=0 then no rain-on-snow occurred, if irain=1 rain-on-snow occurred.

ISNOW Indicates if snowed on the previous day, isnow=0, no snowfall on previous day, isnow>0, snowfall on previous day.

IVEG Determines whether VEGIE is activated or not and which vegetation input file is used.

K1 Count of the number of days modelled, i.e. the number of times the 'do 5001' loop is used.

K2 K2=0 indicates that SNOMO modelled soil in the previous iteration or that SNOMO is not modelling the first iteration. K2=1 indicates that that SNOMO modelled snow in the previous iteration or that it is the first iteration.

K3 K3=0, indicates soil modelled in previous iteration, K3=1, indicates snow modelled in previous iteration.

K25 Count of the days elapsed since the last snowfall.

K30 Indicator to facilitate the calculation of xsntp, in the melt calculations.

KELVIN Air temperature converted to degrees kelvin.

KONTRL Count of the number of days modelled.

LHEATF Latent heat of fusion,  $\text{MJkg}^{-1}$ .

MRSW Meltrate,  $\text{cm snow.day}^{-1}$

MRWE Meltrate,  $\text{mm snow water equivalent.day}^{-1}$ .

NETRAD Net radiation,  $\text{m}^{-2}\text{day}^{-1}$ .

NIPTS The number of times the output time print frequency is divisible by the time steps, used to determine when to print output.

NKONT Used with KONTROL to terminate SNOMD.

NCMATL The number of material layers used in solving the heat flow.

PPTN Precipitation, mm water.

PTERM Heat input to pack by rain-on-snow,  $\text{MJm}^{-2}\text{day}^{-1}$ .

RH Relative humidity, %

SNDF1 Initial snowdepth, cm

SNPPTN Precipitation amount, cm snow.

SNVOL area x depth,  $\text{m}^{-3}$ .

SOILDP depth of soil profile at the base of the snowpack, cm.

SOILTP Soil temperature at depth, taken at soildp, °C.

SPHTI Specific heat of ice,  $2.10 \times 10^3 \text{ Jkg}^{-1}\cdot\text{K}^{-1}$ .

SPBTW Specific heat of water,  $4.18 \times 10^3 \text{ Jkg}^{-1}\cdot\text{K}^{-1}$ .

SSOLTP Surface soil temperature, °C.

STP Surface temperature, °C.

TABSOR Total daily shortwave radiation absorbed at the surface,  $\text{MJm}^{-2}\text{day}^{-1}$ .

TATERM Total daily incoming longwave radiation,  $\text{MJm}^{-2}\text{day}^{-1}$ .

IDTERM Total daily evaporative heat flux,  $\text{MJm}^{-2}\text{day}^{-1}$ .

TGBR Total daily reflected radiation,  $\text{MJm}^{-2}\text{day}^{-1}$ .

THKMK1 Thickness matrix for a 1-layer pack.

THKMK2 Thickness matrix for a 2-layer pack.

THTERM Total daily sensible heat flux,  $\text{MJm}^{-2}\text{day}^{-1}$ .

TIME2 Daily observation time, used to aid the sequential reading of the daily observation time.

TMAX Lapse rate alteration of the maximum daily air temperature.

TMIN Lapse rate alteration of the minimum daily air temperature.

TSOL Total daily incoming solar radiation,  $\text{MJm}^{-2}\text{day}^{-1}$ .



VNEWSN Vector holding new snow values of thermal diffusivity, heat conductivity, emissivity, albedo and density.

VOLDSN Vector holding old snow values of thermal diffusivity, heat conductivity, emissivity, albedo and density.

VSOIL Vector holding soil values of thermal diffusivity, heat conductivity, emissivity, albedo and density (redundant).

WE1 Used in the calculation of depth when converting 'new snow' to 'old snow', cm.

XXX(J,8) Julian date.

XXX(J,1) Observation time.

YEAR Year of the simulation data.

YYY(J,1) Minimum air temperature, °C, table 1.

YYY(J,2) Relative humidity, X, table 2

YYY(J,3) Cloud cover, 0-1, table 3.

YYY(J,6) Wind speed,  $\text{ms}^{-1}$ , table 6.

YYY(J,7) Precipitation, mm water.

YYY(J,9) Maximum air temperature, °C.

(2) TSTM

AB Muge-Möller absorption function.

ACL(8) Coefficient, a, dependent on cloud type, used in the calculation of CTF.

ALPH(IX) Thermal diffusivity of layer IX,  $\text{cm}^{-2}\text{min}^{-1}$ .

AO Atmospheric albedo for Rayleigh scattering.

APRM  $\text{FACTE} \cdot \text{TEMP}^3$ ,  $\text{calcm}^{-2}\text{min}^{-1}\text{C}$ .

B Heat conductivity of surface,  $\text{calcm}^{-2}\text{min}^{-1}\text{C}$ .

BBB(J,I) Y intercept of linear equation, used for table interpolation.

BC Constant used in the calculation of water vapour pressure.

BC'(8) Coefficient, b, dependent on cloud type, used in the calculation of CTF.

BEP Bottom boundary thermal IR emissivity.

BK Bottom surface geometric shape, fraction (0.0-1.0)  
 BPRM Heat conductivity of bottom boundary layer.  
 BTERM Energy contributed by insolation after adjustment using surface absorptivity,  
 $\text{cal cm}^{-2} \text{ min}^{-1}$ .  
  
 CC CLOUD \* CLOUD.  
 COE1 Coefficient used in the calculation of HTERM, DTERM, EF and DTERM, set according to  
 Richardson's Number.  
 COE2 Coefficient used in the calculation of HTERM, DTERM, EF and DTERM, set according to  
 Richardson's Number.  
 COEF Part of calculation of interface values.  
 CLR(8) Coefficient dependent on cloud type, used in the calculation of incoming longwave  
 radiation.  
 CLOUD Cloud cover, fraction (0.1-1.0).  
 CP Specific heat of dry air at constant pressure.  
 CTEMA Air temperature in degrees kelvin, used in calculation of evaporative heat flux.  
 CTF Cloud adjustment factor.  
  
 DAY Julian day used in solving insolation.  
 DCOEF Part of calculation of interface values.  
 DDDT  $dT/dTg$ , part of upper boundary calculation.  
 DECL Solar declination angle.  
 DELT Time step in hours.  
 DEPTH(IY) Matrix holding layer depths.  
 DEPTH(450) Depth of snow or soil profile.  
 DOWNIR Incoming longwave radiation,  $\text{cal cm}^{-2} \text{ min}^{-1}$ .  
 DPRM Heat flux,  $\text{cal cm}^{-2} \text{ min}^{-1}$ , at bottom boundary or temperature in rankines at bottom  
 boundary.  
 DPRM0 Temperature of bottom material, °C, used when LFLUX=0.  
 DPRM1 Heat flux of beneath bottom material,  $\text{cal cm}^{-2} \text{ min}^{-1}$ , used when LFLUXY not equal 0.  
 DTERM Energy flux due to evaporation.  
  
 EA Water vapour pressure of the air.  
 ELF Latitude, radians.

EPSN Emissivity of surface material.  
 ES Water vapour pressure of the surface.  
 ESAI(T) Saturated vapour pressure at temperature T.  
 E(T) Vapour pressure at temperature T.  
  
 F2 Part of the calculation of bottom boundary values.  
 FACTA  $SIGMA * EPSN$   
 FACTD  $FACTD = SIGMA * EK * BEP * TR ** 4$ , used in bottom boundary circulation when there is airspace beneath the bottom layer.  
 FACTE  $FACTE = SIGMA * EK * BEP$ , used in bottom boundary calculation when there is airspace beneath the bottom layer.  
 FACTH  $FACTH = (1000.0 / PRESS) ** 0.286$ , used in solving convection term (HTERM).  
 FK(IX) Heat conductivity of layer IX,  $cal \cdot min^{-1} \cdot cm^{-1} \cdot K^{-1}$ .  
 FPM(J,I) Slope of linear equation, used for table interpolation.  
  
 G Acceleration due to gravity.  
 GTERM Ground heat flux,  $cal \cdot cm^{-2} \cdot min^{-1}$ .  
  
 HEADER 72 character input variable used to print comments on output (not utilized in SNOMD).  
 HTERM Energy loss or gain due to convection,  $cal \cdot cm^{-2} \cdot min^{-1}$ .  
  
 IEFSWT Switch, when =0 will print output only at specified time, if not =0 will print output at every iteration.  
 IEOF Set from 0 to 1 when an EOF is encountered, used to terminate program.  
 III Count of number of interval iterations in calculation of upper boundary values.  
 IMAIL Backward counter of layers, starting with the number of layers.  
 INTR(IX) Beginning sub-layer depth number for layer number IX.  
 IPRNT Backward counter SET+IPRNT. When =1 output is printed.  
 ITER Iteration counter used in finite difference calculation of heat flow equation.  
 ITIME Backward counter initialize as total time steps in hour.  
 IX Layer number starting with top layer.  
 IY Sub-layer depth number.

JMAX           The total number of sub-layers.

K10            Count of the number of internal iterations of TSTM, in order to calculate the daily means of the TSTM calculated energy-budget and temperature variables.

KSQ            von Karman's constant squared.

KTEMPA         Air temperature, degrees kelvin.

KTEMPG         Surface temperature, degrees kelvin.

LAYERS         Count of the profile layers.

LAT            Latitude used in solving insolation.

LFLUXY         Input bottom boundary data control switch. If =0, there is no heat flux through bottom of material, if negative there is no air space beneath bottom material, if positive there is air space beneath bottom material.

LN             Dummy variable to read line number from input file.

M              Secant of solar zenith angle, radians.

MAX(J)         Number of input table values used in table interpolation module.

NCLOUD         Cloud type index number (1-9) used in solving insolation, IR emission.

NETRAD         Net radiation,  $MJm^{-2}day^{-1}$ .

NIT            Number of iterations used in heat flow calculations.

NKONT         Used with KONTRL to terminate SNOMO.

NTABL         Table number.

NX(IX)          $NX(IX)=THK(IX)/SPRQ(IX)$ , number of sublayer of each layer.

OUTCD         Output manipulation variable.

PI             3.141593

PRESS         Atmospheric pressure, mb, used in solving insolation.

PTYME         Beginning time of output=total number of hours minus 24, used in print output module 2.

QSAT(T)       Saturated specific humidity at temperature T.

Q(T)          Specific humidity at temperature T.

REP Emissivity beneath airspace.  
 RBOA Air density, calculated as part of sensible heat calculation.  
 RBQC(IX)  $FK(IX)/ALPH(IX)$ ,  $\text{cal cm}^{-2} \cdot \text{K}^{-1}$ .  
 RI Richardson's Number, index used in solving HTERM, DTERM, HTER, EF.  
 RK Surface beneath airspace geometric shape, fraction (0.0-1.0).  
 RR(IX)  $RR(IX)=DELTA/SFRQ**2$ , part of heat flow equation.  
  
 SAZ Solar azimuth, radians.  
 SCF Used in calculation of sensible heat flux, determined by the Richardson number.  
 SFRQ(IX) Vertical grid spacing in cm in each layer IX,  $\text{cm}^2 \text{m}^{-1}$ .  
 SICF Insolation adjustment due to zenith angle, surface slope and surface aspect angle.  
 SIGMA Stefan-Boltzman constant,  $8.12e-11$ .  
 SLOPE Surface slope, degrees, with horizontal =0 degrees, used in solving insolation.  
 SMALLA Absorbitivity of surface material.  
 SPEED Wind speed,  $\text{cm sec}^{-1}$ .  
 STABN Numerical stability parameter,  $\leq 0.5$  for numerical stability.  
 STOR(1,IY) Estimate sub-layer temperature, degree rankine.  
 STOR(2,IY)  $FK$ , heat conductivity of sub-layer IY,  $\text{cal min}^{-1} \text{cm}^{-1} \cdot \text{K}^{-1}$ .  
 STOR(3,IY)  $RBQC$ ,  $FK/ALPH$ ,  $\text{cal cm}^{-2} \cdot \text{K}^{-1}$ .  
 STOR(4,IY) Constant dimensionless.  
 STOR(5,IY) Initial snow temperature, degree rankine, of initial snow profile.  
 STOR(6,IY) Same as STOR(2,IY).  
 STOR(7,IY) Same as STOR(3,IY).  
 SUMC Count of daily energy totals.  
 SUN Calculated insolation value.  
 SURFAC Surface azimuth, degrees, with south =0, west =+90 and east =-90 degrees, used in solving insolation.  
  
 T Same as TIME.  
 TA Air temperature, degrees rankine.  
 TAC Air temperature, °C.  
 TAK Air temperature, °K.  
 TAL Constant used in the calculation of WATER.

TB Thermal conductivity of bottom material,  $\text{cal cm}^{-2} \cdot \text{C}^{-1} \cdot \text{min}^{-1}$ .  
 TD Dew point temperature used in the calculation of WATER.  
 TEML Surface temperature of material, degrees rankine.  
 TEMR Bottom layer temperature of material in degrees rankine.  
 TFRQ Time step in minutes used in solving heat flow.  
 THK(IX) Layer thickness, in cm of layer IX.  
 TIME Time in hours which material temperatures are estimated.  
 TIMER Sun's hour angle, radians.  
 TITLE Surface temperature, °C.  
 TOTTIM Total number of 24 hour repetitions used in solving heat flow.  
 TPRNT Output time print frequency, minutes.  
 TR Temperature of airspace beneath bottom material.  
 TSK Material sub-layer temperature, °K.  
 TYME Time in hours, used in insolation calculation.

WATER The amount of precipitable water, mm, used in solving insolation.  
 WET Moisture content of surface material.

XXX(J,1) Time in hours for table 1 (air temperature).  
 XXX(J,2) Time in hours for table 2 (relative humidity).  
 XXX(J,3) Time in hours for table 3 (amount of cloud cover).  
 XXX(J,4) Time in hours for table 4 (solar insolation).  
 XXX(J,5) Depth, cm, for table 5 (temperature profile) initial temperature profile, °C.

YYY(J,4) Insolation,  $\text{cal cm}^{-2} \cdot \text{min}^{-1}$ , if 0.0 at 1200 hours, insolation values will be calculated, table 4.

Z Solar zenith angle.  
 ZA Shelter height, cm.  
 ZASH Shelter height, cm.  
 ZZA Surface temperature of material, degree rankine.  
 ZZB Bottom layer temperature of material in degree rankine.

## (3) VEGIE

ATERM Atmospheric IR emission,  $\text{cal cm}^{-2} \text{min}^{-1}$ .  
 ATF(1) Part of the root-finding algorithm.  
 ATF(2) Part of the root-finding algorithm.  
  
 BINT Part of the root-finding algorithm.  
  
 CHO Dimensionless heat or moisture transfer coefficient applicable to the top of a dense canopy.  
 CHH Dimensionless heat or moisture transfer coefficient applicable to the top of a dense canopy.  
 CBG Heat transfer coefficient equation interpolated between ground with no cover, CHO and complete cover, CHH.  
 CP Specific heat of dry air at constant pressure.  
  
 DELTMP Incremental temperature for the root-finding algorithm.  
 DTHETA  $DTHETA = (T_A - T_F) * FACTH / Z_A$ , used in the calculation of the Richardson Number.  
 DU Used in the calculation of the Richardson Number.  
  
 E(T) Vapour pressure at temperature T.  
 EF Latent heat loss to the atmosphere for the foliage.  
 EFF Effective temperature.  
 ELG Latent heat loss to the atmosphere at the ground surface.  
 EP1 Part of the calculation of the energy budget for foliage.  
 EPF Emissivity of foliage.  
 EPSN Emissivity of ground (snowpack) surface.  
 ESAT(T) Saturated vapour pressure at temperature T.  
 EX Coefficient used in the calculation of BTERM, DTERM, HTER and EF, set according to Richardson's Number.  
  
 FACTH Potential temperature.  
 FEB(1) Part of the root-finding algorithm.  
 FEB(2) Part of the root-finding algorithm.

FENB	Energy-budget of the ground and foliage surfaces respectively.
FK(IX)	Heat conductivity of ground (snowpack).
FOLA	Absorptivity of the foliage layer (1-albedo).
FOLGB	Foliage thermal IR emittance, $\text{cal cm}^{-2} \text{min}^{-1}$ .
G	Acceleration due to gravity.
GRNDGB	Ground thermal IR emittance, $\text{cal cm}^{-2} \text{min}^{-1}$ .
HPOL	Foliage height, cm.
HSF	Convective energy flux across the foliage surface.
HSG	Convective energy flux across the ground (snowpack) surface.
HTER	Part of the calculation of HSF.
QAF	Specific humidity of air within the foliage layer.
QF	Specific humidity of the air at foliage height.
QG	Specific humidity of the ground (snowpack) surface.
QSAT(T)	Saturated specific humidity at temperature T.
NDEX	Count of the number of times the energy-budget for the ground or the foliage was calculated.
RA	Atmospheric resistance.
RC	Canopy resistance to water vapour diffusion
RDF	Fraction of potential evaporation rate from foliage.
REFRAD	Surface related radiation, $\text{cal cm}^{-2} \text{min}^{-1}$ .
RHOAF	Density of air near ground surface.
RHOAG	Density of air near the ground surface.
RI	Richardson Number.
RLD	Downward longwave flux over ground (snowpack) surface.
RLU	Upward directed longwave flux radiated from ground (snowpack) surface.
RS	Stomatal resistance.
SFRQ(IX)	Distance of first grid point below the surface.
SG	Incoming solar radiation reaching the ground (snowpack).



**SHEW** Amount of shortwave radiation absorbed by foliage.  
**SIGF** Foliage cover fraction.  
**SIGMA** Stefan-Boltzmann constant.  
**SLOPE1** Part of the root-finding algorithm.  
**SMALLA** Ground (snowpack) surface absorptivity.  
**SOL** Calculated solar insolation reaching the top of the foliage layer.  
**STATE** Arbitrary multiplier (STATE>0) of RS used to account for senescence, stress etc.  
**SURFGB** Surface (foliage + ground surface) thermal IR emittance,  $\text{cal cm}^{-2} \text{min}^{-1}$ .

**T1** Temperature at first grid point below surface, distance SRFQ(IX), in TSTM heat transfer algorithm.

**TA** Air temperature.  
**TEFF** Mean effective temperature.  
**TEFFR** TEFF with reflection incorporated.  
**TEML** Ground (snowpack) surface temperature.  
**TF** Foliage temperature.  
**TF0** Part of the root-finding algorithm.  
**TF4** Part of the calculation of FENB.  
**TGA** Part of the calculation of FENB.  
**THEIAV** Used in the calculation of Richardson's Number.

**UA** Wind speed.  
**UAF** Wind speed of air in the foliage layer.

**WET** Moisture content of ground (snowpack) surface.

**XL1**  $L=f(T_g)$ , used in the calculation of the latent heat of evaporation, a function of air temperature.

**XLNGW** Part of the foliage energy-budget calculation.

**Z0** Roughness length.  
**ZA** Instrument height above ground (snowpack).  
**ZDSP** Zero displacement height.

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