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(E80-10333) FURTHER DEVELOPMENTS OF THE TELL-US MODEL. 1: AN IMPLICIT FINITE DIFFERENCE SCHEME FOR THE NUMERICAL APPROXIMATION OF THE GROUND HEAT FLUX. 2: A SIMPLE ALGORITHM (Joint Research Centre of G3/43 N80-32824 Unclas 00333

TELLUS PROJECT

TELLUS-NEWSLETTER 11 November 1979

FURTHER DEVELOPMENTS OF THE TELL-US MODEL :

I AN IMPLICIT FINITE DIFFERENCE SCHEME FOR THE NUMERICAL APPROXIMATION OF THE GROUND HEAT FLUX

II A SIMPLE ALGORITHM FOR ESTIMATING THE ACTUAL AND POTENTIAL EVAPOTRANSPIRATION OF VEGETATED SURFACES FROM ONE REMOTELY SENSED SURFACE TEMPERATURE NEAR THE DAILY MAXIMUM

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AN IMPLICIT FINITE DIFFERENCE SCHEME FOR THE NUMERICAL APPROXIMATION OF THE GROUND HEAT FLUX

INTRODUCTION

In the appendix of TELLUS-Newsletter 8, May 1979[1] it had been shown that using an explicit finite difference scheme to approximate the flow equation for heat transport in soil, the time- and depth step must be kept small as the stability criterion may not be exceeded and the approximation may not differ too much from the exact solution. It also appeared that the scheme of Du Fort-Frankel is only slightly superior in both respects to the classical explicit difference method.

Implicit finite difference methods are known to be superior to explicit methods, especially with respect to stability. Therefore they permit large time steps, keeping computer calculation time low. Good results have recently been obtained by building an implicit system into the TELL-US algorithm.

THE IMPLICIT FINITE DIFFERENCE METHOD APPLIED

To the one-dimensional heat flow equation (1) at time t and depth x:

$$\frac{\partial T}{\partial t}(x, t) = D * \frac{\partial^2 T}{\partial x^2}(x, t) \qquad (1)$$

the same equation at time $t + \Delta t$ must be added to obtain:

$$\frac{\partial T}{\partial t}(x, t + \Delta t) + \frac{\partial T}{\partial x}(x, t) = D * \frac{\partial^2 T}{\partial x^2}(x, t) + D * \frac{\partial^2 T}{\partial x^2}(x, t + \Delta t) \qquad (2)$$

According to Cranck and Nicolson[2] the left-hand side of Eq. (2) may be approximated by:

$$\frac{2}{\Delta t}(T(x, t + \Delta t) - T(x, t)),$$

neglecting the derivatives of order two and higher.
Writing also the right-hand side of Eq. (2) in difference form, the following scheme can be obtained:

$$\frac{2}{\Delta t}(T(x, t+\Delta t) - T(x, t)) = \frac{D}{\Delta x^2}\left[T(x-\Delta x, t) - 2T(x, t) + T(x+\Delta x, t)\right] +$$

$$\frac{D}{\Delta x^2}\left[T(x-\Delta x, t+\Delta t) - 2T(x, t+\Delta t) + T(x+\Delta x, t+\Delta t)\right] \qquad (3)$$

For a grid expanding in the x-direction Eq. (3) can be written as:

$$\frac{T(x, t+\Delta t) - T(x, t)}{\Delta t} = \frac{D}{\Delta x^2 * EXF ** P * (EXF+1)} \Big[EXF * T(x-\Delta x, t) - (EXF+1)T(x, t) + T(x+\Delta x, t) + EXF * T(x-\Delta x, t+\Delta t) - (EXF+1) * T(x, t+\Delta t) + T(x+\Delta x, t+\Delta t) \Big] \qquad (4)$$

where:

Δt = time step (sec)
Δx = depth step, spacing of the upper two grid points (m)
EXF = expansion factor
P = (2*I-1), I=1 for the first grid point below the surface.

To solve Eq. (4) a set of equations is needed. To give an example, let us assume a soil system divided into four layers, i.e. there are (4 +1) grid points from the surface (x=0) to the lower boundary depth (x=4).
When Eq. (4) is written out for successively x = 1, 2, 3 a set of (4-1) equations is formed, which reads in matrix notation:

$$\begin{bmatrix} F01(1) & 1/EXF & 0 \\ 1 & F01(2) & 1/EXF \\ 0 & 1 & F01(3) \end{bmatrix} * \begin{bmatrix} T(1, t+\Delta t) \\ T(2, t+\Delta t) \\ T(3, t+\Delta t) \end{bmatrix} =$$

$$\begin{bmatrix} F02(1) & -1/EXF & 0 \\ -1 & F02(2) & -1/EXF \\ 0 & -1 & F02(3) \end{bmatrix} * \begin{bmatrix} T(1, t) \\ T(2, t) \\ T(3, t) \end{bmatrix} + \begin{bmatrix} -T(0, t+\Delta t) - T(0, t) \\ 0 \\ -\dfrac{T(4, t+\Delta t) - T(4, t)}{EXF} \end{bmatrix} \qquad (5)$$

where:

$$F0(I) = \frac{TS * D}{DS**2*EXF**(2I-1)*(EXF+1)} \quad , I = 1, 2, 3$$

$$F01(I) = -((F0(I) * EXF + F0(I) + 1)/F0(I)/EXF)$$

$$F02(I) = ((F0(I) * EXF + F0(I) - 1)/F0(I)/EXF)$$

Vector T(x, t) is the known temperature profile at time t,
$T(4, t+\Delta t) = T(4, t)$ is the lower boundary temperature,
$T(0, t+\Delta t)$ is at first approximated as: $2 * T(0, t) - T(0, t-\Delta t)$.

Everything on the right-hand side of Eq. (5) is known and results in a single vector, in the program called PROD2. The linear system that remains can easily be solved by converting the matrix in upper triangular form and back-substitution. The solution vector is the temperature profile in the soil at $t + \Delta t$.
The temperature at $x = 0$ and $x = 1$ are entered into the energy balance equation. The first one will be modified during the iterative process. While $T(1, t + \Delta t)$ is strongly influenced by the estimated $T(0, t + \Delta t)$, it is clear that considerable errors may arise when the soil heat flux is calculated from the modified surface temperature and the fixed value at $x = 1$. Therefore the estimated $T(0, t + \Delta t)$ will be replaced by the surface temperature that comes out of the iterative process and the whole procedure from Eq. (5) will be repeated once.

RESULTS

In Tables 1A and 1B the results of calculations with the implicit version are shown. The data set obtained during the Joint Flight Experiment at Grendon Underwood, U.K. on September 12-13, 1977 was used for these calculations.

Table 1A may be compared with tables 1A and 2A of TELLUS Newsletter 8. Resemblance is best with Table 2A of that paper. This means that there remain differences with what can be seen as the most precise calculations, i.e. Table 1A of Newsletter 8. However, these differences are not dramatically large.

To recapitulate: a high heat capacity value of 2×10^{7} J/kg/K as originally applied in TELL-US is not acceptable as shown in Newsletter 8. A realistic heat capacity value has to be accompanied by such a small time step, in order to keep the explicit numerical scheme stable, that total calculation time becomes extraordinarily high (alternative 1). With an explicit scheme and a realistic heat capacity value some speeding up is possible by increasing the depth step to around 2 cm and the time step to five minutes (alternative 2). The third alternative, the proposed implicit scheme with a time step of one hour and a depth step of 2 cm, reduces calculation time with a factor four compared to alternative 2 (12 resp. 50 sec).

It appeared from the treatment of several other data sets that TELL-US becomes rather sensitive to heat capacity, when a realistic value is taken. Therefore it may be suggested to vary the heat capacity value with thermal inertia, which is from a physical point of view certainly defendable. A look-up table calculated with a floating heat capacity value is shown as Table 1B.

CONCLUSION

Given the attractive short calculation time and the numerical stability it is strongly recommendable to use the proposed implicit finite difference scheme to simulate the ground heat flux.

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TABLE 1A - Look-Up Table Calculated with the Implicit Version of the TELL-US Model

Heat capacity: $2 * 10^6$ J/m^3/K
Calculation time step: 3600 sec
Depth step: 2 cm
Total calculation time: 12 sec

Thermal Inertia		Surface Relative Humidity					
		0.0	0.20	0.40	0.60	0.80	1.00
800.	D. TEMP.:	43.7	34.0	29.2	26.0	23.7	21.9
	N. TEMP.:	7.4	4.9	2.3	0.3	-0.7	-1.3
	C. EVAP.:	-7.0	-2.7	-0.3	1.3	2.3	2.9
1200.	D. TEMP.:	41.8	33.1	28.5	25.5	23.2	21.5
	N. TEMP.:	9.7	7.0	5.2	3.8	2.5	1.6
	C. EVAP.:	-7.0	-2.8	-0.5	1.0	2.1	2.8
1600.	D. TEMP.:	40.1	32.2	27.9	25.0	22.8	21.2
	N. TEMP.:	11.3	8.6	6.7	5.3	4.1	3.2
	C. EVAP.:	-7.0	-2.9	-0.6	0.9	2.0	2.8
2000.	D. TEMP.:	38.5	31.4	27.4	24.6	22.5	20.9
	N. TEMP.:	12.5	9.7	7.9	6.4	5.3	4.3
	C. EVAP.:	-7.0	-3.0	-0.7	0.9	2.0	2.8
2400.	D. TEMP.:	36.9	30.6	26.8	24.2	22.2	20.6
	N. TEMP.:	13.0	10.4	8.6	7.2	6.1	5.2
	C. EVAP.:	-6.9	-3.1	-0.8	0.8	2.0	2.9

TABLE 1B - Look-Up Table Calculated with the Implicit Version of the TELL-US Model

Floating heat capacity value: HCAP = 1E6 + 2E6/1600 * (THIN-890) $J/m^3/K$
Calculation time step: 3600 sec
Depth step: 2 cm
Total calculation time: 12 sec

Thermal Inertia		Surface Relative Humidity					
		0.0	0.20	0.40	0.60	0.80	1.00
800.	D. TEMP.:	43.7	34.0	29.3	26.1	23.7	21.9
	N. TEMP.:	8.5	5.9	4.1	2.0	0.7	0.0
	C. EVAP.:	-7.0	-2.7	-0.3	1.3	2.3	3.0
1200.	D. TEMP.:	41.8	33.1	28.6	25.5	23.3	21.5
	N. TEMP.:	10.1	7.5	5.7	4.2	3.0	2.1
	C. EVAP.:	-7.0	-2.8	-0.5	1.0	2.1	2.9
1600.	D. TEMP.:	40.1	32.2	27.9	25.0	22.8	21.2
	N. TEMP.:	11.3	8.6	6.7	5.3	4.1	3.2
	C. EVAP.:	-7.0	-2.9	-0.6	0.9	2.0	2.8
2000.	D. TEMP.:	38.6	31.4	27.3	24.5	22.4	20.8
	N. TEMP.:	12.2	9.4	7.5	6.1	5.0	4.0
	C. EVAP.:	-7.0	-3.0	-0.7	0.8	2.9	2.8
2400.	D. TEMP.:	37.2	30.6	26.7	24.1	22.0	20.5
	N. TEMP.:	12.8	10.0	8.2	6.7	5.6	4.7
	C. EVAP.:	-7.0	-3.1	-0.8	0.8	1.9	2.7

Programming Aspects of the Implicit Approach
(The soil is divided into 10 layers between the surface and the lower boundary depth)

```
C       - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C       To calculate for every newthermal inertia value

        CAP = 2E6         (or a function of thermal inertia)
        COND = (THIN(J)**2)/CAP
        Do 2 I = 1, 9
        F0(I) = TS *COND/CAP/((EXF+1) * DS **2 * EXF **(2 * I-1)
        F01(I) =-((F0(I)*EXF + F0(I) + 1)/F0(I)/EXF)
    2   F02(I) = ((F0(I)*EXF + F0(I) - 1)/F0(I)/EXF)

C       Description of matrix A (9*9)

        Do 11 I = 1, 9
        Do 11 J = 1, 9
   11   A(I, J) = 0.0
        Do 13 I = 1, 9
   13   A(I, I) = F01(I)
        Do 14 I = 1, 8
   14   A(I, I + 1) = 1/EXF
        Do 15 I = 2, 9
   15   A(I, I - 1) = 1

C       Description of matrix B (9*9)

        Do 16 I = 1, 9
        Do 17 J = 1, 9
   17   B(I, J) = -A(I, J)
   16   B(I, I) = F02(I)
C       - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C       To calculate every new time step:
C       matrix B multiplied with vector T(x, t) results in the vector
C       PROD1(x).
C       The vector T(x, t) is called TOLD(x)

        Do 100 I = 1, 9
        PROD1(I) = 0.0
        I MIN 1 = I-1
        IF(I MIN 1. LT. 1) I MIN 1 = 1
        I PLUS 1 = I+1
        IF(I PLUS 1. GT. 9) I PLUS 1 = 9
        Do 100 J = I MIN 1, I PLUS 1
  100   PROD1(I) = PROD1(I) + B(I, J) * TOLD(J)
```

```
C         calculation of PROD2(x)
C         T(0, t + Δ t) is called: STNEW
C         T(0, t)       is called: STOLD
C         T(0, t - Δ t) is called: STVOLD
CCCC      STNEW is only a first approximation

          STNEW = 2*STOLD - STVOLD
          PROD2(1) = PROD1(1) - STOLD - STNEW
          Do 200 I = 2, 8
  200     PROD2(I) = PROD1(I)
          PROD2(9) = PROD1(9) - 2 *LBT/EXF

C         calculation of new temperature profile
C         the solution vector T(x, t + Δt) is called TNEW(x)

C         COPY A IN D
          Do 300 I = 1, 9
          Do 300 J = 1, 9
  300     D(I, J) = A(I, J)
          EPS = 1.0 E-10
          Do 306 I = 1, 8
          Do 306 J = I+1, 9
          IF(ABS(D(J, I)). LT. EPS) GOTO 306
          HOLD = D(J, I)
          Do 307 K = I, 9
  307     D(J, K) = D(I, K) - D(I, I)/HOLD * D(J, K)
  306     PROD2(J) = PROD2(I) - D(I, I)/HOLD * PROD2(J)
          TNEW(9) = PROD2(9)/D(9, 9)
          Do 308 IP = 1, 8
          I = 9-IP
          IPLUS 1 = I+1
          SOM = 0.0
          Do 309 J = IPLUS 1, 9
  309     SOM = SOM + D(I, J) * TNEW(J)
  308     TNEW(I) = (PROD2(I) - SOM)/D(I, I)
```

All energy balance components now can be calculated as a function of first approximation STNEW.
The modified STNEW coming out of the iterative process must be entered again in the equation:
PROD2(1) = PROD1(1) - STOLD - STNEW and the procedure to calculate vector TNEW must be repeated.

A SIMPLE ALGORITHM FOR ESTIMATING THE ACTUAL AND POTENTIAL EVAPOTRANSPIRATION OF VEGETATED SURFACES FROM ONE REMOTELY SENSED SURFACE TEMPERATURE NEAR THE DAILY MAXIMUM

INTRODUCTION

At present, and without considering other approaches or methods of calculation (SEGUIN, 1978; JACKSON et al., 1977), two models are available to the TELLUS project to calculate daily evapotranspiration and soil moisture content from remotely sensed surface temperatures:

1. The TERGRA-model (SOER, 1977) was originally developed for grassland. It is still under investigation how the model could also be applied to other, more structured crops.

2. The TELL-US-model (ROSEMA and BYLEVELD, 1977) was set up for bare or scarcely vegetated soils. According to later developments (KLAASSEN and ROSEMA, 1979), it should be applicable in the same form also to vegetated surfaces.

It has to be remarked that TERGRA in its basic form did not estimate soil moisture content (on the contrary: soil moisture potential at the beginning of simulation is an important input parameter), nor did it make use of a remotely sensed crop temperature. In later versions the model was adapted to the evaluation of soil moisture employing one remotely sensed surface temperature close to the daily maximum. For practical remote sensing purposes, the need for a large number of place-dependent input parameters still constitutes a drawback of the model.

TELL-US uses two remotely sensed surface temperatures, close to the daily maximum and minimum temperatures, respectively. In this way, the course of the surface temperature through the day is more or less fixed. This method permits to vary two parameters, surface relative humidity that predominantly determines the day temperature and thermal inertia that mainly influences the night temperature. The simulated daily course of the surface temperature is a function of these two variables. If, for a certain combination of these two variables, there is sufficient resemblance between the simulated and measured minimum and maximum surface temperatures, these values of surface relative humidity and thermal inertia are assumed to be valid for the system. Then, surface relative humidity permits the calculation of daily evapotranspiration and thermal inertia gives information about soil moisture content.

TELL-US needs only a few place-dependent input parameters and is therefore operationally more attractive than TERGRA. Its application to vegetated surfaces, as proposed by KLAASSEN and ROSEMA (1979), would therefore seem advantageous. Nevertheless, this application gives rise to a number of problems which will be discussed in the next section. A simplified algorithm is proposed which should avoid some of these problems.

PROBLEMS RELATED TO THE APPLICATION OF TELL-US TO VEGETATED SURFACES

1. During Daytime:

   The ground heat flux under a closed vegetative cover is known to be small during daytime, about one order of magnitude less than net radiation. For its energy input, the soil depends on the vegetation (radiative exchange between soil and crop) and on the relatively still air inside the canopy (conductive heat exchange). The soil surface will therefore usually be cooler than the vegetative cover. In TELL-US, the crop temperature will be adapted as the upper boundary temperature of the soil system. This will result in an overestimate of the ground heat flux. As the surface temperature through the day is more or less fixed, an underestimate of the latent heat flux is inevitable, as net radiation and the sensible heat flux are fixed together with the surface temperature in the simulation process.

2. During Nighttime:

   At night, the vegetation also has an insulating effect and usually crop temperature will be lower than the soil surface temperature. Given the boundary condition in TELL-US, again the soil heat flux is overestimated and, the crop temperature being fixed, thermal inertia will be strongly underestimated.

   In the case of vegetated surfaces, thermal inertia has exactly the same physical meaning as in the case of bare soils: it determines the thermal properties of the soil and thus, indirectly, it gives information about soil moisture content. Contrary to bare soil, for a vegetated surface, also surface relative humidity, or a corresponding parameter such as stomatal resistance, is correlated with bulk soil moisture content. It should be understood that in the case of bare soil, surface relative humidity and thermal inertia are independent variables while in the case of a vegetated surface they are strongly related. Therefore, it seems superfluous to distinguish between surface relative humidity and thermal inertia in the latter case and there remains little reason to use the nightly minimum surface temperature, as:

a) the thermal inertia value obtained will give a wrong impression of soil moisture content, and

b) windspeed is often low during the night which poses problems due to the great variability of the air temperature under these conditions (HUYGEN and REINIGER, 1979).

THE NEW APPROACH

The simplified algorithm is a derivation of the TELL-US model. The following simplifications have been introduced:

1) Only the hours between sunrise and sunset are taken as the simulation period.

2) The ground heat flux is assumed to be 10% of net radiation.

3) Instead of surface relative humidity and thermal inertia, the course of the daily surface temperature is calculated for different but constant values of bulk stomatal resistance.

For a certain stomatal resistance there will be agreement between the remotely sensed surface temperature close to the daily maximum and the simulated crop temperature at that time. The stomatal resistance obtained in this way permits calculation of the daily evapotranspiration. It will be shown that potential evapotranspiration can also be obtained by establishing a minimum value for the bulk stomatal resistance.

The input parameters of the model are the same as for the TELL-US model, i.e. daily maximum surface temperature, albedo, emissivity, crop height, slope dip and direction and hourly measurement of incoming short- and longwave radiation, dry- and wet bulb temperature and windspeed. The incoming longwave radiation may eventually be approximated by a Brunt-type formula.

A listing of the computer program is available on request.

TEST OF THE ALGORITHM

The algorithm was compared with results obtained with the TERGRA model for a simulated Super Test Data Set, given in Table 1. Results of the test are shown in Fig. 1 with an example of the output of the model, given in Table 2.

With the simplified algorithm potential evapotranspiration can be found by establishing a minimum value for bulk stomatal resistance. In the literature critical values for leaf water potential can be found up to which potential transpiration will be maintained. RIJTEMA and ABOUKHALED (1975) give a value of -1000 kPa for grass and wheat, whereas EHRLER et al. (1978) give a value of around -1500 kPa for wheat.

With equation (1), used in TERGRA, leaf water potential may be translated into bulk stomatal resistance:

$$RC = \sqrt{1/GHC} * (0.05 * (PSIL/100) ** 2.1 + 400/(RS + 1.5)) \quad (1)$$

where:

RC = stomatal resistance (s/m)
GHC = mean crop height (m)
PSIL = leaf water potential (kPa)
RS = incoming solar radiation (W/m^2)

For the Super Test Data Set, as shown in Fig. 1, the simplified algorithm calculates a total daily transpiration of 4.9 mm when the leaf water potential is kept at -1500 kPa. TERGRA also calculates a potential daily transpiration of 4.9 mm (Fig. 1). For the data set in question one may conclude that the assumption of a critical leaf water potential of -1500 kPa leads to an estimate of potential evapotranspiration comparable to that of the TERGRA model. However, it should be stressed that Eq. (1) was basically developed for grass. To be valid for crops with a different roughness, a suitable form of Eq. (1) should first be obtained.

Actual evapotranspiration may be obtained by varying the bulk stomatal resistance until there is agreement between the simulated and the measured crop temperature. In Fig. 1 the actual evapotranspiration as a function of crop temperature at 13.00 H, as calculated by TERGRA, is described by the full curve. The points marked X are values calculated by the simplified algorithm. For the atmospheric conditions of a rather high evaporative demand, characteristic of this data set, the agreement between the two models is rather good with a maximum difference of 5% in the total daily evapotranspiration.

CONCLUSION

The proposed simplified evapotranspiration algorithm should be useful to estimate from remotely sensed surface temperatures both potential and actual evapotranspiration, important parameters in present day crop yield forecasting. It can, in principle, be applied to all crop types once the surface is completely covered. As with the TELL-US model a multidimensional look-up table can be constructed which should permit the mapping of evapotranspiration on a pixel by pixel basis.

Problems in the application of the algorithm are the estimation of roughness for different crop types and, probably, the assumption of a bulk stomatal resistance constant during the simulation period.
Likewise, the questions posed by the interpretation of remotely sensed surface temperatures of structured crops, still remain open.

The algorithm should be further tested with experimental field data.

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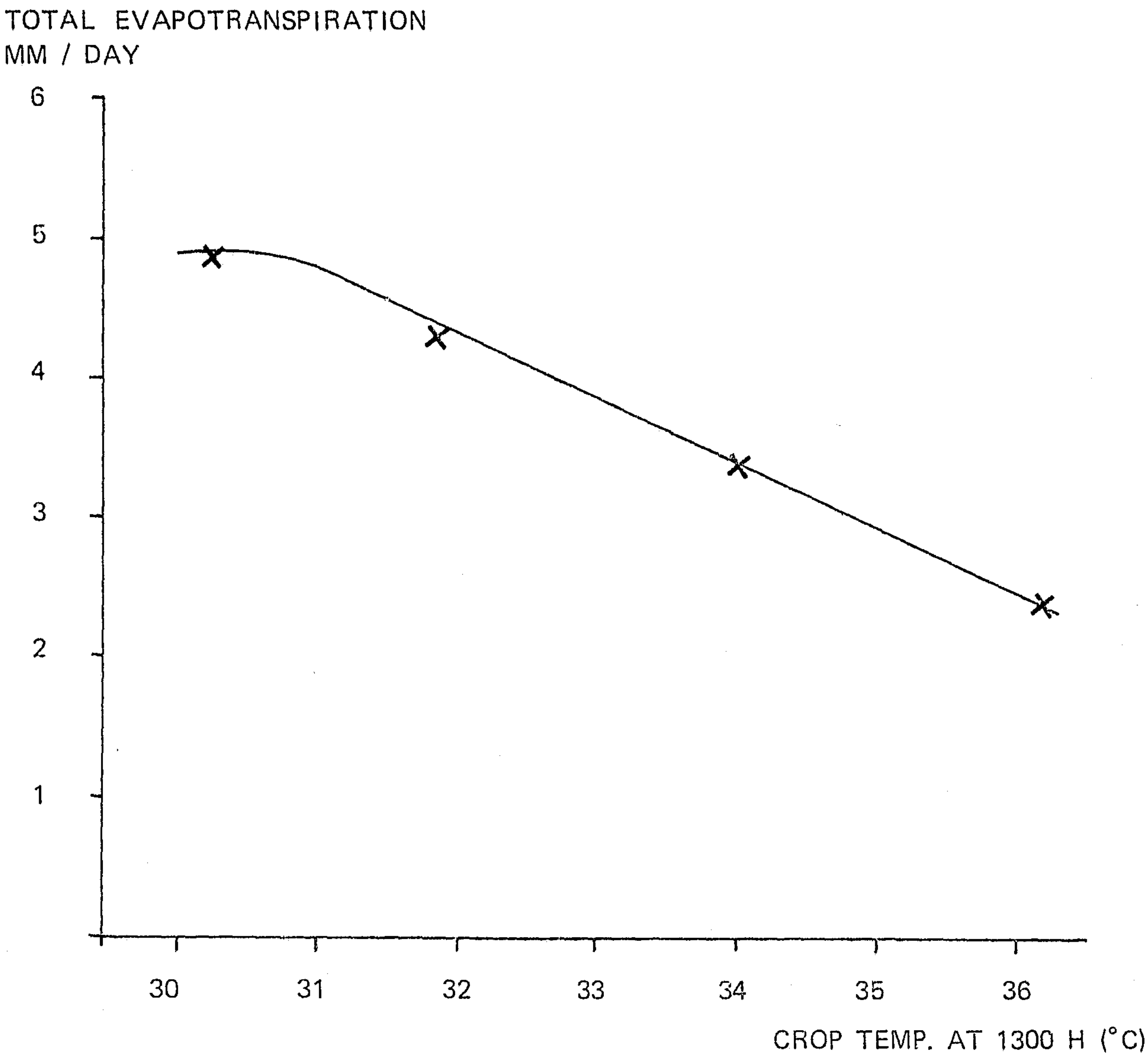

Fig. 1 : Total daily evapotranspiration as a function of crop surface temperature at 13.00 H.

Full curve : Calculated with TERGRA

× : Calculated with the simplified model

TABLE 1 - Super Test Data Set - Grassland

DAY: 186.

LATITUDE: 40.00

CROP HEIGHT(M): 0.14

EMISSIVITY :0.9500

ALBEDO=0.330/(1+0.6SIN(SOLAR ELEVATION))

SIMULATION PERIOD: FROM 4.00 UNTILL 20.00(HOUR.MIN)

SURFACE TEMPERATURE REMOTELY SENSED AT: 13.00H

SOIL COVER FRACTION: 1.0

SLOPE DIP : 0.0

SLOPE DIR.: 0.0

METEOROLOGICAL INPUT DATA (HOURLY VALUES):

TIME	SOLAR IRR.	LW.INC.RAD.	DRY BULB TEMP(2M)	WET BULB TEMP.(2M)	WINDSPEED(2M)
4.0	0.6	307.1	285.45	284.65	1.5
5.0	41.0	334.5	286.35	285.35	1.4
6.0	153.9	347.4	289.65	286.95	1.3
7.0	306.3	355.2	293.65	288.65	1.3
8.0	480.7	359.0	296.05	290.55	2.3
9.0	626.2	363.5	297.35	292.85	2.7
10.0	737.3	367.3	298.85	293.75	2.2
11.0	811.1	374.2	299.25	294.15	2.6
12.0	844.7	377.0	298.75	294.75	4.5
13.0	813.7	379.1	299.05	295.45	3.7
14.0	742.6	370.2	299.55	295.55	3.1
15.0	624.2	360.4	299.25	295.25	2.4
16.0	469.7	358.3	299.25	295.25	2.9
17.0	305.9	357.5	298.25	294.75	3.1
18.0	152.7	344.1	296.75	293.35	2.8
19.0	36.3	334.3	295.25	292.45	2.8
20.0	1.0	323.8	293.55	292.05	3.1

TABLE 2 - Output

RNT	CHF	H	ALF	U	SPEC.H.	TPA	SUPT	RA	PC	EVAP
-27.7	2.8	24.8	0.0	1.5	0.0081	12.2	4.4	394.81	40.68	0.0
-9.7	1.0	10.2	-1.1	1.4	0.0084	13.7	11.9	169.98	40.68	0.00
60.4	-6.0	-0.9	-53.4	1.3	0.0087	16.5	16.6	128.04	40.68	0.08
157.9	-15.8	-9.7	-132.5	1.3	0.0089	20.5	21.4	113.46	40.68	0.19
233.2	-28.3	-24.1	-230.9	2.3	0.0101	22.9	24.3	71.02	40.68	0.34
390.7	-39.1	-50.9	-291.0	2.7	0.0124	24.2	27.2	59.39	40.68	0.43
470.2	-47.0	-73.7	-349.4	2.0	0.0130	25.7	30.1	70.42	40.68	0.51
536.6	-53.7	-86.3	-396.2	2.6	0.0134	26.1	30.5	59.04	40.68	0.58
574.6	-57.5	-112.	-404.2	4.5	0.0144	25.6	29.4	39.39	40.68	0.60
545.0	-54.5	-109.7	-381.3	3.7	0.0153	25.9	30.2	45.63	40.68	0.56
477.4	-47.7	-80.6	-349.0	3.1	0.0152	26.4	30.1	52.81	40.68	0.51
374.6	-37.5	-54.6	-282.3	2.4	0.0149	26.1	29.1	64.81	40.68	0.42
259.2	-25.9	-17.5	-215.3	2.9	0.0149	26.1	27.0	69.12	40.68	0.32
142.5	-14.3	10.7	[illegible]	2.1	0.0146	25.1	24.5	60.41	40.68	0.20
31.6	-3.2	38.2	[illegible]	[illegible]	0.0133	23.6	21.2	74.57	40.68	0.10
-47.2	4.7	56.1	[illegible]	[illegible]	0.0128	22.1	18.3	80.73	40.68	0.02
-72.2	7.2	64.5	[illegible]	[illegible]	0.0120	20.4	16.6	70.66	40.68	0.0

	CROP RESISTANCE				
	0.0	40.68	75.00	150.00	300.00
CROP TEMPERATURE AT 12.00H :	27.54	30.20	31.72	33.89	36.16
EVAPORATION FROM WET VEGETATION (MM/DAY) :	5.73				
POTENTIAL TRANSPIRATION (MM/DAY) :		4.96			
ACTUAL TRANSPIRATION (MM/DAY) :			4.32	3.43	2.45