

# KRC planetary surface temperatures: Helplist

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## 1 Introduction

This document is intended to help the expert user of KRC set up an input file that addresses their goals and will generate the kind of output they desire. It is assumed that the user is familiar with the KRC journal article: H.H. Kieffer, Thermal model for analysis of Mars infrared mapping, J. Geophys. Res.: Planets, v.118, 451-570 (2013) [Ref. 1]

The evolution of KRC code is contained in: *evolve.txt*

A crude diagram of the call architecture is in: *flow.txt*

Capabilites new in version 3.4.x are decribed in: *V34UG.tex* (or .dvi or .pdf versions)

Eclipse capabilites (V3.5) are described in: *eclipse.tex* (“)

[[ Development for thermal beaming of asteroids is described in: *Beaming.tex* (“) ]] not released

### 1.1 Notation use here

The following fonts styles have been partially implemented:

File names are shown as *file*.

Program and routine names are shown as **PROGRM** [,N]

where **N** indicates a major control index.

Code variable names are shown as **variab** and within equations as **variab**.

Input parameters are shown as **INPUT** and within equations as **INPUT**

When KRC was made double-precision, an '8' was added to many routine names, both as the source-code file and as they are called; this 8 is commonly omitted in this documentation.

## 2 METHOD

The program is designed to compute surface and subsurface temperatures for a global set of latitudes at a full set of seasons, with enough depth to capture the annual thermal wave, and to compute seasonal condensation mass. For historic reasons, the code has substantial optimization. Although developed for Mars, there are generalities that allow this code set to be used for any solid body with any spin vector, in any orbit (around any star), with or without an atmosphere; this is also the source of some of the complexity.

Method is explicit forward finite differences with exponentially increasing layer thickness and binary time increase with depth where allowed by stability. Depth parameter is scaled to the diurnal thermal skin depth. Initially starts at 18 hours with the mean temperature of a perfect conductor. Second degree perturbation is applied at the end (midnight) of the (third) day; this jumps the mean temperature of all layers and the lower boundary to equal the mean surface temperature.

Boundary condition treatment:

Perturbation solution of quartic equation at surface for each iteration; temperature gradient assumed uniform in top interval.

Lower boundary may be insulating or constant-temperature, or fixed heatflow

Atmospheric Radiation: KRC uses a one-layer atmosphere that is grey in both the solar and infra-red regions. The default atmospheric parameters are based on estimates of Mars' gas and aerosol properties.

Two-stream Delta-Eddington model for insolation; direct onto sloped surface and diffuse, with possible twilight extension. The atmosphere temperature is based on Delta-Eddington solar absorpction and IR opacity

Keplerian orbital motion; seasons are at uniform increments of time. Mean orbital elements are pre-calculated for any epoch (all planets and several comets and asteroids) by the PORB code set.

Units are SI, except for use of days for orbital motion and rotation period

Note: Insolation at a season is computed on the assumption that the body is spinning at a fixed orbital position for that season. This is equivalent to assuming the “day” (sol) is short compared to the “year” (orbital period). This is equivalent to all longitudes having the same insolation. Hence, KRC is not appropriate for bodies with small synchronous rotations to their year, such as Mercury.

Options:

- Different Physical properties below a set layer (IC).
- May define many zones via an input table
- Regional slope. Self- or far-field heating
- Three (for Mars) ways to handle seasonal global pressure variation .
- Up to two zones of temperature-dependent conductivity and specific heat
- Non-Lambertian solar absorption.
- Global geothermal heat flow.
- Eclipses by the planet or satellite.
- Incident flux from a planet onto a satellite, thermal is sinusoidal.
- For sloped surfaces, the “far-field” radiation can be defined by a prior KRC run.

Atmosphere condensation:

- Global integral of frost-gas budget can control surface pressure.
- Can have virtually any single condensing gas desired.
- Allows different surface elevation for each latitude zone.
- Zonal frost saturation temperature tracks local surface pressure.
- Option for cap albedo to depend upon mean daily insolation.
- Frost albedo can vary continuously with frost amount

## 2.1 Convergence Notes

Convergence prediction routine can't jump more than one time constant ( $\text{TAU} = X^{**2}/2$ )  $\tau = x^2/2$  for the total thickness. Therefore, if  $X(N1)$  is small, make DDT smaller than usual. If  $\text{DELJUL}$  is much smaller than  $(X(N1))^{**2}/2$   $X_{N1}^2/2$ , then DDT can be as large as 0.3. Otherwise DDT must be about 0 for the prediction routine to work well (it assumes the 3rd derivative to be 0).

## 3 INPUT FILE

KRC asks for the name of an input file, default is *krc.inp*, and an output file, default is *krc.prt*. If the desired file is not in the current directory, then its name must be surrounded by single quotes.

All parameters for KRC are set by a formatted text file. An example is *master.inp* , which has default values for a 19 latitude set for a run of three martian years, with the last output to disk. Parameter values are listed below their titles, which are in many cases identical to the code name, and last character of the title is above the last location in the field. Thus, integer values MUST be aligned. Titles with a leading " " indicate that the value is not used. The recommended procedure is to copy *master.inp* and edit only the values you wish to change. The number of lines of Latitudes and Elevations must match the value of N4, e.g., 2 lines for N4=11:20, entries beyond the N4 position may be left blank or contain the end of the line. The 7 lines following Elevations are a geometry matrix, default is for Mars orientation and orbit in 2010. This matrix should not be edited; but can be replaced by the matrix for other objects by the results of running PORBMN .

The parameter title lines are skipped, so that you could put comments there carefully.

The first input line is always KOLD,KEEP [I\*], which sets file usage; these are described in §7. If KOLD=0, then a full set of input values is read.

If and only if there is a third non-zero integer, then KRC will read the next card as six debug flags, IDB1 to IDB6, which are normally zero. See §12 below

The next (normally second) line is free text where you can outline the purpose of your run; up to 84 characters.

Change lines may follow immediately after the geometry matrix (see §4) . The end of definition of a "case" is indicated by a "0/" line. Two successive "0/" lines ends the run.

The source code for 'krcc8m.f' indicates for many of the parameters which subroutine sets it; as the routine name in lowercase just below the parameter name.

- - - - -

```

Type 1 Real parameters (8F10.2) =====
  Surface Properties
1  ALB    Surface albedo
2  EMIS    Surface emissivity
3  SKRC    Surface thermal inertia [ $\text{J m}^{-2} \text{s}^{-1/2} \text{K}^{-1}$ ] { cal cm * 4.184e4}
4  COND2   Lower material conductivity (IC>0)
5  DENS2   Lower material density (IC>0)
6  PERIOD  Length of solar day in days (of 86400 seconds)
7  SPHT    Surface specific heat [ $\text{J}/(\text{kg K})$ ] {cal/(g K) * 4184.}
8  DENS    Surface density [ $\text{kg}/\text{m}^3$ ] {g/cubic cm. *1000}
- - - - -
  Atmospheric Properties
9  CABR    IR opacity of dust-free atmosphere of PTOTAL surface pressure
10 AMW     Molecular weight of the atmosphere
11 ABRPHA  First Clausius-Clapeyron coefficient  SatPrA
12 PTOTAL  Global annual mean surface pressure at 0 elev., Pascal[=.01mb]
             If <=1.; no atmosphere at all.
             If KPREF=2, global average of atmosphere plus cap system.
13 FANON   Mass-fraction of mean atmosphere that is non-condensing
14 TATM    Atm temp for scale-height calculations
- - - - -
15 TDEEP   Fixed bottom temperature. Used if IIB>=1.
16 SPHT2   Lower material specific heat (IC2>0)
- - - - -
  Dust & Slope Properties
17 TAUD    Mean visible opacity of dust, solar wavelengths
18 DUSTA   Single scattering albedo of dust
19 TAURAT  Ratio of thermal to visible opacity of dust
20 TWILI   Twilight extension angle [deg]
21 ARC2    Henyey-Greenstein scattering asymmetry factor
22 ARC3    Minimum allowable numerical convergence factor  Theory is 1.
23 SLOPE   Ground slope, degrees dip. Only pit may slope beyond pole.
24 SLOAZI  Slope azimuth, degrees east from north. <-360 is a pit
- - - - -
  Frost Properties
25 TFROST  Minimum Frost saturation temperature
             may be overridden by local saturation temperature (LVFT)
26 CFROST  Frost latent heat [ $\text{J}/\text{kg}$ ] {cal/gm*4184. [ Not used if
27 AFROST  Frost albedo, may be overridden (LVFA) [ TFROST never
28 FEMIS   Frost emissivity [ reached
29 AF1     constant term in linear relation of albedo to solar flux
30 AF2     linear term in relation of albedo to solar flux units=1/flux
             Afrost = AF1 + AF2 * <cos incidence> SOLCON / DAU^2
31 FROEXT  Frost required for unity scattering attenuation coeff. [ $\text{kg}/\text{m}^2$ ]
             the greater of this and 0.01 is always used.
32 fd32    Second Clausius-Clapeyron coefficient  SatPrB
- - - - -
  Thermal Solution Parameters
33 RLAY    Layer thickness ratio
34 FLAY    First physical layer thickness (in skin depths)
35 CONVF   Safety factor for classical numerical convergence
             0 for no binary time division of lower layers
             >0.8 for binary time division. Larger is more conservative
36 DEPTH   Total model depth (scaled) (overrides FLAY if not 0.)
37 DRSET   Perturbation factor in jump convergence. If = 0., then
             all layers reset to same average as surface layer. Else,
             does quadratic curve between surface and bottom averages

```

```

38 PHOG      Reflectance photometric function control
              0=Lambert <-1=Lommel-Seeliger +=Kheim-Vasavada
              else (-1< x <0) Minnaert with exponent -x (is positive)
              See V34UG.pdf, Sections 5 and 13
39 GGT       Surface boundary condition iteration test on temperature
40 DTMAX     Convergence test: RMS layer T changes in a day
-----
Orbit Geometry & Constants
41 DJUL      Starting Julian date of run -2451545 (J2000.0) (N5>0)
              If LKEY (logical item 12) is set True, this is desired Ls of
              first disk output date (set by JDISK: integer item 12)
42 DELJUL    Increment between seasons in Julian days (if N5>1)
43 SDEC      Solar declination in degrees. (if Not LPROB)
44 DAU       Distance from Sun in astronomical units (if Not LPROB)
45 SUBS      Aerocentric longitude of Sun, in degrees. For printout
              only. Computed from date unless N5=0 (for printout only)
46 SOLCON    Solar constant. Total stellar irradiance at 1 AU [W/m^2]
47 GRAV      Surface gravity. MKS-units
48 AtmCp     Specific heat at constant pressure of the atmosphere [J/kg/K]
-----
Temperature dependent conductivity. Ignored unless LKOFT set.
49 ConUp0    Constant coef for upper material
50 ConUp1    Linear in  $k=c_0+c_1x+c_2x^2+c_3x^3$  where  $x=(T-220)*0.01$ 
51 ConUp2    Quadratic "
52 ConUp3    Cubic coeff. "
53 ConLo0    Constant coef for lower material
54 ConLo1    Linear as for ConUp above
55 ConLo2    Quadratic "
56 ConLo3    Cubic coeff. "
Temperature dependent specific heat. Ignored unless LKOFT set.
57 SphUp0    Constant coef for upper material
58 SphUp1    Linear in  $k=c_0+c_1x+c_2x^2+c_3x^3$  where  $x=(T-220)*0.01$ 
59 SphUp2    Quadratic "
60 SphUp3    Cubic coeff. "
61 SphLo0    Constant coef for lower material
62 SphLo1    Linear as for SphUp above
63 SphLo2    Quadratic "
64 SphLo3    Cubic coeff. "
-----
Computed REAL values
65 HUGE      = 1.D308 large REAL*8 constant with margin
66 TINY      = 1.D-307 small REAL*8 constant with margin
67 EXPMIN    = 700.d0 safe negative R*8 exponent
68 YRIDAY    Length of a year in days
69 FLOST     Atm frost 'lost' in the atm. in last day at current lat./season
              v356 and later, this is spare.
70 RGAS      = 8.3145 ideal gas constant (MKS=J/mol/K)
71 TATMIN    Atmosphere saturation temperature
72 PRES      Local surface pressure at current season
73 OPACITY    Solar opacity for current elevation and season
74 TAUIR     current thermal opacity at the zenith
75 TAU EFF    effective current thermal opacity
76 TATMJ     One-layer atmosphere temperature
77 SKYFAC    fraction of upper hemisphere that is sky
78 TFNOW     frost condensation temperature at current latitude
79 AFNOW     frost albedo at current latitude
80 PZREF     Current surface pressure at 0 elevation, [Pascal]

```

```

81 SUMF      Global average columnar mass of frost [MKS]
82 TEQUIL    Equilibrium temperature (no diurnal variation)
83 TBLOW     Numerical limit (Blowup) temperature
84 HOURO     Output Hour requested for "one-point" model
85 SCALEH    Atmospheric scale height
86 BETA      Atmospheric IR absorption
87 DJU5      Current Julian date (offset J2000.0 ala PORB convention)
88 DAM       Half length of daylight in degrees
89 EFROST    Frost on the ground at current latitude [kg/m^2] {g/cm^2 * 10.}
90 DLAT      Current latitude
91 COND      Top material Thermal conductivity (for printout only)
92 DIFFU     Top material Thermal diffusivity (for printout only)
93 SCALE     Top material Diurnal skin depth (for printout only)
94 PIVAL     pi
95 SIGSB     Stephan-Boltzman constant (set in KRC)
96 RADC      Degrees/radian

```

#### Type 2 Integer Parameters (8I10) =====

To simplify coding logic, some may be input as 0, meaning none or never,  
but will be modified automatically to very large, Indicate by: -->never

```

1  N1      # layers (including fake first layer) (lim MAXN1)
2  N2      # 'times' per day (lim MAXN2). Must be an even number,
           should be a multiple of N24 and NMHA.
3  N3      Maximum # days to iterate for solution (lim MAXN3)
           This can be 1, but then must use DELJUL ~= PERIOD
           If N3 lt 3, first day starts on midnight. else at 18H
4  N4      # latitudes (lim MAXN4). Global integrations done for N4>8
5  N5      # 'seasons' total for this run. If 0, then DAU and SDEC will be
           used as entered for a single season.
6  N24     # 'hours' per day stored, should be divisor of N2 (lim MAXNH)
7  IIB     Bottom control: 0=insulating, -1=constant temperature
           -2=start all layers =TDEEP & constant temperature
           += geothermal heat flow in milliwatts/m^2
8  IC2     First layer (remember that 1 is virtual) of changed properties.
           <3 will be changed to 999 =homogeneous
-----
9  NRSET   # days before reset of lower layers first season; >N3=no reset
10 NMHA    # 'hour angles' per day for printout (no limit)
11 NRUN    Run #; appears in some printout. Initalized as 0 and
           auto-increment whenever disk file opened. May be modified
12 JDISK   Season count that disk output is to begin. <1 -->never
13 IDOWN   Season at which to read change cards
14 I14     Index in FD of flexible print
15 I15     "" and >100 is code for special output to fort.77 via tun.f
16 KPREF   Mean global pressure control. 0=constant
           1= follows Viking Lander curve 2=reduced by global frost, but
           then N4 must be >8, and latitudes must be monotonic increasing
           and must include both polar regions (no warning for your failure)
-----
17 K4OUT   Disk output control: See details in DISK BINARY FILES section
           Three modes of direct access Fortran files; one case per file.
           -=KRCCOM(once), then TSF [,TPF [,TAF]]
           -1 saves TST, the surface kinetic temperature
           -2 also saves TPF, the top-of-atmosphere bolometric temperature
           -3 also saves TAF, the 1-layer atmosphere kinetic temperature
           0=KRCCOM,LATCOM each season

```

```

1:49=KRCCOM,DAYCOM for the last latitude; each season
Modes of bin5 file for multiple cases. ONLY 52 IS STILL SUPPORTED
x51=(Hours, 2 min/max, lat, seasons, cases)
52=(hours, 7 items, lat, seasons, cases)
x54=(many seasons, 5 items,lats, cases)
x55=(many seasons,9 items, cases)
x56=(packed T hour and depth, latitude,season,case)
18 JBARE J5 season count at end of which to set frost amount to 0. 0-->never
19 NMOD Spacing of season for notification. minimum of 1
20 IDISK2 Last season to disk for which TDISK prints notice
Note: Special routines MKRC,KRCA and TYEARP use TDISK differently
- - - - -

```

```

Computed Integer values But note 24 may be input
21 KOLD Season index for reading starting conditions
22 KVALB Flag: to use seasonal surface albedo ALB
23 KVTAU Flag: 1:TAUD=SEASTAU(SUBS) 2:CLIMTAU opacities for dust and ice
24 ID24 Flag: Direct Access file word type: 4=R*4 else=R*8
this single item in 21:40 can be set by a change line: 2 24 x 'ID24' /
25 NUMVER Version number as an integer
26 KFARAC Sets reporting of TFAR8 reads
27 NBKRC Number of bytes in KRCCOM, not used anywhere
28 NFD Number of real items read in
39 NID Number of integer items read in
30 NLD Number of logical items read in
31 N1M1 Temperature vrs depth printout limit (N1-1)
32 NLW Temperature vrs depth printout increment
33 JJO Index of starting time of first day
34 KKK Total # separately timed layers
35 N1PIB N1+IB Used to control reset of lowest layer
36 NCASE Count of input parameter sets in one run
37 J2 Index of current time of day
38 J3 Index of current day of iteration
39 J4 Index of current latitude
40 J5 Index of current "season"

```

#### Type 3 Logical Parameters (10L7) =====

```

1 LP1 Print program description. TPRINT(1)
2 LP2 Print all parameters and change cards (2) for current case
3 LP3 Print hourly conditions on last day (3), every lat, every season
4 LP4 Print daily convergence summary (4)
5 LP5 Print latitude summary (5)
6 LP6 Print TMIN and TMAX versus latitude and layer (6)
7 LPGLOB Print global parameters each season
8 LVFA Use variable frost albedo. Uses AF1 & AF2 (real # 29,30)
9 LVFT Use variable frost temperatures
10 LKOFT Use temperature-dependent conductivity and specific heat
- - - - -
11 LPORB Call PORB1 just after full input set
12 LKEY Treat DJUL (real item 41) as the Ls of the first output
season, set by JDISK [the 12'th integer input]
13 LSC Read change cards from input file at start of each season
14 LZONE Use a zone depth table file to set layers.
15 LOCAL Use each layer for scaling depth
16 LD16 Print hourly table to fort.76 [TLATS]
SUBS,DLAT,ALB,SKRC,TAUD,PRES at end of every latitude
and every hour: Hour T_K IR_Inc Solar T_Planet

```



```

17 LD17    Print temperatures at end of last day of each season
18 LD18    Print of parameters and layers was done after last change
19 LD19    Output to fort.79 [TLATS] insolation and atm.rad. arrays
           for every time-step for every latitude, every time tlats is called.
20 LONE    (Computed) Set TRUE if KRC is in the "one-point" mode
=====

```

followed in 'krccom' by:

84 character KITLE Description/purpose of this run.

20 character DAYTIM run date and time

Latitude(s) (10F7.2) N4 latitudes in degrees

Latitudes to be in order; south to north. [[If last latitude is  
.LE. 0, will assume symmetric results for global integrations]]

Elevation(s) (10F7.2) N4 values in Km corresponding to latitudes

Orbital Parameters (LPORB=T) Format identical to that produced by PORB  
program set ASCII file output. So these can be directly pasted with an  
editor. See porbc8m.f

## 4 PARAMETER CHANGES

Fortran list-directed. Change the values in KRCCOM. Lines of four (or more) white-separated values, a "/" terminates the read and leaves remaining values unchanged. The 4 required items are:

- 1: Type (integer): see table below
  - 2: Index in array (integer): as listed in Input File table above
  - 3: New value, numeric: 0.=false. Will read as real and convert as needed.
  - 4: File name or a reason: Text string within single quotes; or a /  
Missing quote may cause run failure.
- [after a / (forward slash) nothing is read, so you can use for comments]

The print file will list each change as read, followed by the title of the changed item. It is a good idea to look at this print to be sure you changed what you intended.

Type	Meaning	Valid Index
0	End of Current Changes	any
1	Real Parameter	1:NFDR=64
2	Integer Parameter	1:NIDR=20
3	Logical Parameter	1:NLDR=20
4	New Latitude Card(s) Follow	any
5	New Elevation Card(s) Follow	any
6	New Orbital Parm Cards Follow (LPORB Must be True)	any
7	Text becomes new Title	any
8	Text becomes new output or input file name. Value ignored if not mentioned	
	if index=3, name of far-field temperature file to read	
	value 0/1 sets report of each read off/on	
	if index=4, name of far-field temperature file to read for held Tatm.	
	if index=5, name of type 5x (52) packed output file	
	if index=21, name of output direct-access file. Lasts for one case	
	if index=22, call SEASALB to read variable ALBEDO	
	if index=23, call SEASTAU to read variable TAUD	
	if index=24, call CLIMTAU to read Mars climate	

```

    if index=25, name of new zone table to read
9   Complete new set of input follows          any
10  Text becomes new One-Point input file name
11  This is a set of parameters for "one-point" model
    For this type, 9 values must appear in a rigid format
12  Set of 2*4 coefficients for T-dep. conductivity. List-directed IO
13  Set of 2*4 coefficients for T-dep. specific heat. List-directed IO
14  Set of 12 values for eclipse. See -/Doc/v35/eclipse.pdf sec. 5.5
e.g. 14  1 5.2026 71492. 0.6711D6 3121.6 3.551 0.01 6000. 12. 2 77 77 / Europa
15  Set of 7 values for flux load from primary body (planet). " sec. 7.1
e.g. 15  0.62 0. 0. 0.21 0.21 0. 12. / Jupiter flux on Europa, nearside center
16  Latitude and name for high-time-resolution surface temperature file
    See eclipse.pdf section 8

```

#### 4.0.1 Type 8 notes

Each of the index actions can be terminated by using a file name of less than 4 characters; i.e. "off".

For Type 8, SEASALB and SEASTAU read 2-column, white-separated text files.

To start variable albedo, use input card:

```
8 22 0 'AlbedoFileName' / Variable albedo text file name
```

Can revert to constant albedo by using a non-existent file name. E.g.,

```
8 22 0 'badName' / turn variable albedo off
```

Text table files of value versus season will be read at the start of a run. These will apply to ALL latitudes. See example *valb1.tab*

Variable dust opacity done the same way, with 22 being replaced with 23

CLIMTAU files have dust and ice opacity over season and latitude. Uses BIN5 to read a binary array (72 seasons, 36 latitudes, 2=dust/ice) of opacities. The sample file *THEMIS1yearDustIce.bin5* is described in section [159] of Ref 1.

Index=3 or =4 will read type -n file to be used for far-field surface and atmosphere. See §9.3

Index=5 writes a dense type 52 file that can hold many cases and contains virtually all the input and output values! See §A. It cannot be input to KRC but an IDL reader **readkrc52** is provided.

#### 4.0.2 Other types

For Type 12 and 13, 8 white-space-separated coefficients must follow after the type on the same line, with no intervening index or text

Type 14, 15, 16 apply to all following cases until a corresponding change line with the 2nd item 0 .

## 5 Contents of COMMONS

COMMON /KRCCOM/ Input and transfer variables. See *krcc8m.f*

COMMON /DAYCOM/ Layer and time-of-day items. See *dayc8m.f*

COMMON /FILCOM/ File names. See *filc8m.f*

COMMON /HATCOM/ Store post-2003 items. See *hatac8m.f*

COMMON /LATCOM/ Latitude-dependent items. See *latc8m.f*

COMMON /PORBCM/ PORB system geometry matrix. See *porbc8m.f*

COMMON /UNITS/ Logical units for I/O and errors. See *unic8m.f*

Because the binding routines to IDL are intolerant of any errors, changes to KRCCOM, DAYCOM and LATCOM are avoided if possible. Rather, in 2004July HATCOM was added as a "catch-all" for any new items.

A listing of all Fortran commons can be generated by these Linux commands:

```
cd /home/hkieffer/krc/src [replace top part of path with local installation]
```

```
rm allinc.txt
```

```
cat *c8m.f > allinc.txt
```

Table 1: Return codes, as seen at KRC main, after return from TSEAS, and maybe from lower routine:

in	value	Comment
TCARD		2:19
	2	restarted from disk record
	3	continue from current conditions
	4	Switch to "one-point" mode
	15	END of data
	16	Error reading buffer of one-point or T-dependent coefficients
	17	Early End Of File for above
TDAY8(1		initiation [by +20]
	23	Some layer unstable
	24	Too many Layers generated by zone table
	27	TFINE initiation failed
TLATS		21:29 from lower TDAY(2 [by +20]
	22	numerical blowup
	25	ECLIPSE failed
	28	ECLIPSE reaches midnight (possible near pole of body)
	31:36	Error n-30 in TFAR, see below [by +30]
	37	Using far-field file, but N2 is not an integral multiple of the number of hours in the fff.
	38	Using fff, but that has no match to current latitude
	39	ECLIPSE return error at current latitude.
TSEAS		none in TSEAS itself
TFAR		Error when arg3 (R*8) returns negative: use magnitude +40
	40+	magnitude below, +3 for 2nd file
	1	request for file information, but none open
	2	invalid number of temperature types (records per season)
	3	an I/O error occured in TFAREAD
TDISK		In TDISK, will STOP. Error opening Direct Access file. See also §6.3

## 6 Error Returns

If you run into errors that are not related to blunders in the input file, please contact your source for KRC.

### 6.1 “Case had fatal error”

Message to both the print and error files, the value printed is explained in Table 1

### 6.2 Tday Blowup

In initiation step TDAY8(1

(QQ.LT. ARC3): convergence factor less than safety factor specified by input iten 1:22, which should never be less than 0.8. In theory, this factor should be 1.0, but KRC is generally stable down to 0.8 for temperature-independent materials. For temperature-dependent materials, KRC uses the values at the forecast global mean temperature; if this error occurs, increase ARC3 and the layer thicknesses.

(TSUR.LE. 0. .OR. TSUR.GT.TBLOW): Surface kinetic temperature outside reasonable range. TBLOW is set (in TLATS) as twice the equilibrium temperature for the surface perpendicular to the specified insolation at the current season.

In either case, control goes to 340 in TDAY; iteration is terminated and several values are sent to the print file. TDISK is called to output the current season and to close the file. TPRINT is called to print out the full input set and the latest daily convergence. The return code is set to 2.

### 6.3 TDISK error explanations

Below are extracts from the FORTRAN code. Material between single quotes is printed; items following on the same line are variables whose value will be printed.

'P' goes to print file. 'E' goes to error log.  
'DA' is direct-access @ indicates action taken

P: 'TDISK Error: CODE,KREC,JREC=',CODE,KREC,JREC  
E: ' TDISK:1, ERROR OPENING FILE. IOSTAT=',IOS  
E: ' IOD2=',IOD2,' status=',CSTAT,' recl=',NRECL  
E: ' file= ',FDIRA

Trying to open DA file, but failed: reading a file that does not exist or writing a file that already exists.  
@ KRC stops

E: 'TDISK: K4OUT invalid, will use -3:',K4OUT  
Trying to open a DA file, but the value of K4OUT in the input file invalid.  
@ Locally sets type to .tm1 and proceeds

E: 'TDISK: Record smaller than KRCCOM. R\*8 words:',NWTOT,NWKRC  
Some change to the source code krcc8m.f has generated a file record length smaller than KRCCOM.  
Fatal, @ will stop

P: 'Bad size change, CLOSE file. See Error File'  
P: 'Closed direct access file. Type=',ITOP  
E: 'TDISK: Invalid Change of N24, NLAT, or #to Disk for K4OUT=52'  
E: 'TDISK: ',N24,MM1, N4,JJJ(4),J,JJJ(5)  
Change to any of these would change the size of a Type 52 array, not allowed.  
@ Closes the file, file will be unreliable

E: ' TDISK:2, WRITE, BUT NO FILE OPEN'  
Trying to write a seasonal record, but file is not open  
@ Will continue calculations

E: 'TDISK:3, READ, BUT NO FILE OPEN'  
Trying to read a DA record, but the file-open earlier failed  
@ Will continue calculations, results unreliable

E: 'TDISK:4, no file was open'  
Asked to close a file that was not open. No action.

E: 'TDISK:5,wrong conditions: LOPN2,ITOP',LOPN2,ITOP  
Trying to write KRCCOM to a DA file, and either the file was not open or the open file was the wrong type. No other action.

E: 'TDISK:7, Asked to close but LOPN4 false',JREC  
Some routine wants to write a Type 52 file, but contents are not defined.  
Should never occur; programming error. @ KRC continues

E: 'TDISK:5, Called with invalid CODE=',kode  
Should never occur; programming error. @ KRC continues

## 7 DISK BINARY FILES

The routine TDISK is used to read or write seasonal/global direct-access binary files and to write multi-case type 52 (.bin5) files. The first season to write is specified by JDISK, all following seasons will go to the same file. For direct-access files type 0 or positive, each file record consists of KRCCOM plus LATCOM or KRCCOM. plus DAYCOM. Type -n have one record the contains KRCCOM followed by n records of temperature for each season. Writing of type 52 and direct-access files are

independent of each other and may be simultaneous.

Binary files are REAL\*8, with the single exception that type -n may be written as REAL\*4 (to save space for really large runs) by setting ID24 to 4 (see §4; R\*4 files can be read with the TFAR and TFAREAD routines, which will auto-detect the precision; no other use of binary R\*4 files with KRC versions 3.1.1 or later has been tested!

## 7.1 Items which control file I/O

KOLD & KEEP on first input line

KOLD: 0= input card set follows; else=disk record number to start from, then will read any change cards.

If LPORB in old file was True, then there must be a PORB card set as the set of lines following the KEEP,KOLD line

KEEP: 0= close disk file after reading seasonal record KOLD;

>0= value of JJJJ at which to start saving seasons in same disk file [overrides JDISK].

To start from a prior seasonal run, need to determine the record corresponding to the desired season;

KOLD=J5\_target - JDISK(old) ; >0

set KEEP=1, change card J5=number of new seasons, set K4OUT.

JDISK sets the first season to save results

N5 sets the last season to run

K4OUT sets the direct-access record content: (ignored for Type 52)

-1:-3 First record is COMKRC=/KRCCOM/= FD(96R8),ALAT(37R8),ELEV(37R8),  
ID(40I4), LD(20L4), KITLE(C84), DAYTIM(C20) Sizes set in krcc8m.f  
Then records of TSF, [TPF, [Tatm]]

For each season. Each record is MAXNH,MAXN4 = 96\*37 = 3552 real\*8 words

0 Will output records of KRCCOM+LATCOM for each season

1:49 Will output records of KRCCOM+DAYCOM for the last computed latitude.

If a change ' 8 5 0 <filename> ' has been set, then will write a type 52 bin5 file at the end of a run, with dimensionality of 5. This allows multiple cases, each with a "prefix" for each case consisting of 4 size integers (converted to Float) followed by KRCCOM; after this may come vectors of parameters versus season. The next-to-last dimension is increased to allow room for the prefix to be embedded in the bin5 array. Each dimension is adjusted to the necessary size. Each case has the same structure; this simplifies coding although some items are then present redundantly.

KRC input items that would increase any of the bin5 dimensions are not allowed to change between cases in a file. Decrease in these sizes are allowed, however this will leave regions of the file undefined and the only clue will be the values in krccom that are stored for each case. Increases to larger than the value for the first case will cause an error and closing of the file. This restriction is on:

N5-JDISK: number of output seasons

N4: number of latitudes

N24: number of hours output

Although KRC allows the N1, the number of layers, to change between cases the IDL type 52 reader **readkrc52** will only extract the number in the first case, so N1 should not increase between cases.

The first 4 words of the prefix, and thus of the bin5 array, are:

(1)=FLOAT(NWKRC) ! Number of words in KRCCOM  
(2)=FLOAT(IDX) ! 1-based index of dimension with extra values  
(3)=FLOAT(NDX) ! Number of those extra  
(4)=FLOAT(NSOUT) ! [Available of other use]

See also Appendix A for a detailed description and how it is unpacked.

52=(N24 hours, 7 items, N4 lats, NDX+ seasons, cases)

The prefix section contains: sub\_array(seasons,5)(0-based index)

0)=DJU5 1)=SUBS 2)=PZREF 3)=TAUD 4)=SUMF

The 7 items are: 1)=TSF 2)=TPF 3)=TAF 4)=DOWNVIS 5)=DOWNIR

6) packed with [NDJ4,DTM4,TTA4, followed by TIN(2+

7) packed with [FROST4,AFR04,HEATMM, followed by TAX(2+

The number of layers for TIN and TAX is the smaller of: the number computed and that fit here.

----- The other type 5x listed below are no longer supported -----

51=(N24 hours, 2: TSF TPF, N4 lats, NDX+ seasons, cases)

The prefix is identical to Type 52

0)=DJU5 1)=SUBS 2)=PZREF 3)=TAUD 4)=SUMF

54= (seasons, 5 items, NDX +nlat, cases)

Items are (0-based index):

0= TSF=surface temperature at 1 am, 1= TSF at 13 hours,

2= HEATMM=heat flow, 3= FROST4=frost amount,

4= TTB4 = predicted mean bottom temperature

The prefix contains DJU5

55= (seasons,NDX+ items,cases). For seasonal studies at one latitude

ITEMS intended to be recoded as needed. Initial version is 9 items:

[Tsur@ 1am,3am,1pm, spare, Tplan @1am,1pm, Surface heat flow,

frost budget, T\_bottom]

The prefix contains DJU5

Can hold very large number of seasons and cases.

THIS MODE DOES NOT SUPPORT CONTINUATION RUNS

56= [vectors&items, latitudes, NDX+ seasons, cases]

The first dimension is: TSF for all hours, TPF at all hours,

T4 for all layers at midnight, then FROST4,HEATMM,TTA4

The prefix is identical to Type 52

Once a disk file is opened, any records written will go into that file until a new filename is specified (Type 8 Change line), which closes the current file. It is best to ensure that output file does not already exist. If the file already exists, new output may be written in same area, even if the old file was larger than needed.

## 7.2 Maximum sizes

Values for latest version of KRC in this section are in square brackets. All are firm-coded in krcc8m.f

For any run, even without recorded output, there are three limits:

maximum number of layers, N1 [50]

maximum number of times of day, N2 [393216]

maximum number of iteration days, N3 [16]

For all file output types, there are two more limits:

The number of latitudes N4 [37]

Number of stored hours N24 [96].

All of these are checked and limited in TCARD before a run starts.

MAXN5 and MAXN6 are not limits for standard KRC.

### 7.2.1 Direct access files

For type 0, -1, -2 and -3 files, each recorded season is a logical record, so there is no limit to the number of seasons allowed.

Table 2: Guide to file connections.

Type8 Index	Routine used	UNITS IOD	UNITS flag	FILCOM name	Discussion
3	TFAR:4	IOD3=13	LOPN3	FFAR	fff Tsurf; must remain open
4	TFAR ?	IODA=14	LFATM	FFATM	ttt Tatm; must remain open
5	TDISK:6,2,7	—	LOPN4	FDISK	.type 52 output, calls BINF5 calls primeio, brief
21	TDISK:1,2,4	IOD2=2	LOPN2	FDIRA	write .tmx, till closed
22	SEASALB	IOD1=1	KVALB	FVALB	read, calls READTXT360, brief
23	SEASTAU	IOD1	KVTAU=1	FVTAU	read, calls READTXT360, brief
24	CLIMTAU	—	KVTAU=2	FVTAU	read, calls BINF5 calls primeio, brief error could leave FID open
25	READZONE	IOD1=1	LZONE	FZONE	read,zone table, brief
-	input	IOIN=3	-		input file. Default is krc.inp or [any].inp
-	keyboard	IOKEY=5			manual input
-	print	IOSP=7	-		print file. default is [any].prt
-	errors	IOERR=9	-		eLog[date:time to msec]

### 7.2.2 Type 52 files

For type 52, the primary limit is the total words available to accumulate results into a bin5 array; this is the parameter KOMMON in krcc8m.f, currently set at 10,000,000. The size needed for one case is approximately:  $N_{24} \times 7 \times N_4 \times (N_5 - J_{\text{DISK}} + 3)$ .

All five limits mentioned above are in effect.

The number of cases allowed is set by the size of case one, and printed as MASE at the end of the first case in the print output. Cases beyond the maximum that can be stored will be executed, but not saved.

## 7.3 Logical units

See table 2. Note that setting IDB1 to 99 will redirect all IOPM and IOERR output to IOSP so that all print output is chronological there. This can be useful in tracking down causes of errors.

### 7.3.1 ASCII Output Files

Reconstructed 2017oct01

----.prt General results. Things in output are controlled by LP1:6 & LPGLOB  
and most of the six IDBG values

eLog---.--- Error Log, named for time as yyyyymmddThhmmss.fff

fort.43, 44 and 47. tfine8.f , Usually only if eclipse case. see eclipse.tex

fort 71 tlats8.f: Debug: surface conditions

fort.72 tlats8.f: Debug: temperatures and frost prediction

fort.75 tlats8.f: Debug: geometry details

fort.76 tlats8.f: mimic Mike Mellon ASCII files

fort.77 tun8.f: Special items, firmcoded

Table 3: Guide to logical units used. 'D' means only if D-lines are compiled

name	number	routine[s]	purpose
IOD1	1		explanation file — zone table (briefly open)
IOD2	2	tdisk	direct-access write ( and read)
IOIN	3		Input file: defined in units.inc
IOKEY	5		keyboard: " "
IOPM	6		moniter: " " Can be redirected
IOSP	7		print file: " "
IOERR	9		errors: " " was IOPM
IOD3	13		direct-access far-field, read only
IODA	14		direct-access far-field, atm, read only
ifun	^	tfar	iod2 or ioda
?	?	BINF5	primio system, brief
-	43	tfine	
-	44	tfine	
-	46	tday	
-	47	tday	
-	47	tfine	
D	71	tlats	
D	72	tlats	
D	73	tday	
D	75	tlats	
-	76	tlats	
-	77	TUN8	special user firm-code output
D	88	tlats	

## 8 Use of logical units

## 9 Optional input files

### 9.1 Text

#### 9.1.1 Zone depth table

Name is defined by a change card: 8 25 x 'fileName' / . May have up to 20 lines of comments before a "C\_END" line. Then each row define a zone and must contain 4 columns:

Col 1: ZDZ; thickness, m

Col 2: ZDEN; density, kg/m<sup>3</sup>

But: =-1=use DENS, -2=use DENS2

Col 3: ZCOND; Conductivity, SI Units. [ If negative then col 4 is a pointer: 1=upper material, 2=lower material

Col 4: ZSPH; Specific heat, SI Units. [ as in real input 3:16, +2 for at T-dependent at Tglobal

Must be at least 3 zones; otherwise could use two layers within input parameters.

The thickness of the last zone is ignored; KRC will fill out to N1 geometric layers.

Must not be any trailing blank lines

The file name is read in by TCARD; TDAY will call READZONE to read the file. Then the zones will be expanded into an appropriate number of layers. If the zone definitions violate the convergence stability requirements or the number of layers assigned, the case will be skipped with a warning.

MAXN1 [firm-coded as 50 in KRCCOM] zones are allowed, any beyond this will be ignored.

If the number of layers generated exceeds N1, a warning is printed and the case is skipped.



### 9.1.2 Seasonal albedo table

Name is defined by a change card: “ 8 22 x 'fileName' / “ and stored as FVALB in FILCOM. May have up to 20 lines of comments before a “C.END” line. Then each row must contain 2 columns.

Col 1:  $L_S$  in degrees

Col 2: surface albedo

Values of Col 1 must be within 0:360 and monotonically increasing.

Must not be any trailing blank lines

Values apply to all latitudes. Active flag is KVALB

The file name is read in by TCARD; TLATS will call SEASALB to initiate or to get a values for a specific season. SEASALB calls READTXT360 to read the file. SEASALB will do linear interpolation in season and handle wrap-around.

Example: *-/krc/tes/valb1.tab*

### 9.1.3 Seasonal opacity table

Similar to the albedo table with these exceptions:

primary routine is SEASTAU.

Name is defined by a change card: 8 23 x 'fileName' and stored as FVTAU in FILCOM

Col 2: visual dust opacity

Active flag is KVTAU=1

Example: *-/krc/tes/SmithTau.tab*

## 9.2 Binary: Seasonal climate table

Name is defined by a change card: 8 25 x 'fileName' / and stored as FVTAU in FILCOM; name is shared with variable tau as cannot be active at once. The active flag is KVTAU=2.

A binary file of .bin5 format. [Seasons,latitude,item] assumes Seasons and latitude on a rectangular, uniformly-spaced, grid. Item 1 is visual opacity. Item 2 is ice-cloud opacity [could be optional, but coded to be present].

File is read and bi-linear interpolated by CLIMTAU; which is called by TLATS.

Firm-coded for 72 seasons and 36 latitudes, both uniformly spaced.

Example: */work1/mars/opacity/THEMIS1yearDustIce.bin5*

## 9.3 Far-field files (fff)

Prior to version 3.4.1, for sloped surfaces the radiation coming from “below the horizon”, the “far-field”, was assumed to be from a surface with the same temperature and properties as the sloped surface being calculated; this is called “self-heating” And, the atmosphere temperature was calculated as if the entire surface was at the current slope. Version 3.4.1 introduced the concept of a far-field file (fff), output from a prior KRC run, that set the far field surface temperature and was used for the atmosphere temperature.

Version 3.6.1 allows the far-field surface temperature and the atmosphere temperature to come from different prior runs. Specifically, the atmosphere would typically be from a “flat” run; as commonly the surface regionally, say over a radius similar at least as great as the atmospheric scale height, is close to level. The far-field surface viewed by a slope is typically flat or tilted toward the current slope, i.e., of opposite azimuth.

Reminder: KRC direct-access -n files have records that are a fixed size, based on the maximum sizes of N24 and N4, and have one record for each temperature stored , Ts [Tp, [Ta]] (based on the value of K4OUT) for each season. The original KRC run input parameters are stored in the first record.

However, only the emissivity is extracted from the first record. The atmosphere paramters of an fff should match the current run.

FFF's can be written as REAL\*8 (the default) or REAL\*4, depending on the values of ID24. When read, the precision is auto-detected and a REAL\*4 fff is converted to REAL\*8 in the TFAREAD routine

Type -n direct-access files are written by a change line:

8 21 0 'fineName.tmx' / output a direct-access filere

which lasts only for one case.

Type -n direct-access files to be used as fff are read by a change line

```
8 3 0 'fineName.tmx' / read a fff to be used for far surface
```

```
8 4 0 'fineName.tm3' / read a fff to be used for atmosphere
```

which is active until turned off by using a similar change line except the entire file name has no more than 4 characters; e.g.,

```
8 3 0 'off' /
```

If there is no atmosphere, use is simple. Type -1,-2, or -3 can be used, but only Tsurface is active.

With an atmosphere, it is more complex. An 8 3 ... change line will read a file to be used for the far surface. If that file is type -3, its atmosphere values will be used. If not, then an 8 4 ... change line specifying a type -3 file must be present; such a line overrides any active fff atmosphere values. Both 8 3 ... and 8 4 ... values remain in effect until turned off by a corresponding change line with a short file name.

```
8 4 0 'fineName.tmx' / read a fff to be used for the atmosphere
```

### 9.3.1 fff Algorithm Details:

All interface with an fff, except closing the unit, is through TFAR.

TCARD:

```
8 3 ... closes logical unit IOD3, sets IOPN3 false, and updates the FFAR file name
```

```
8 4 ... closes logical unit IODA, sets LFATM false and updates the FFATM file name
```

KRC:

```
If IOPN3 false and FFAR length 4+, calls TFAR(1 to open FFAR
```

```
If LFATM false and FFATM length 4+, calls TFAR(11 to open FFATM
```

```
If that fff case was sloped, prints warning
```

```
If the only type -3 read is FFAR, uses that for Tatm and sets FAME true (same file for both T's)
```

```
If case has an atmosphere, and fff surface is specified but no fff atm is specified; case will be skipped as invalid.
```

TSEAS:

```
Calls TFAR to interpolate to current season
```

```
If LOPN3 true, updates Tsurf using FFAR. If fff is type -3, Tatm is also updated.
```

```
If KRC case has an atmosphere and LFAME=false, then updates Tatm using FFATM
```

TFAR:

```
Updates IOPN3 or LFATM when it opens the associated file
```

```
Returns as many temperatures as are in the file.
```

## 10 Handy things

The first "hour" in printout and output arrays is 1/N24 of a sol after midnight. E.g., the last time is midnight, not the first.

Atmospheric scale height, SCALEH, depends upon physical constants GRAV [input] and TATMAVE which (2007nov) is TATM [input] for the first season and thereafter the diurnal average of the prior season.

To run and save various cases for a single season, set N5 and JDISK to 1.

To extract a detailed day by saving DAYCOM to disk, set JDISK=N5, set a new file name, and set K4OUT to desired latitude index (normally 1):

To run continuously with output every K (1-3) days, set DELJUL=K\*PERIOD This will force prediction terms to near 0.

```
setting N3=1 will turn off all prediction.
```

```
set GGT large (to avoid iteration for convergence)
```

```
set NRSET=999 (to avoid reset of layers)
```

To continue a run with new parameters (e.g., DELJUL)

```
3 21 1 'flag set to continue'
```

Note: changing DELJUL will cause reset of DJUL

Must increase the value of N5: e.g., 2 5 [bigger] 'Increase stopping season'

```
Reset will not occur because J5 continues incrementing
```

## 10.1 To run two material types

Set IC2 to the first layer to have the lower material properties ( $\geq 3$ )

Set COND2 to the lower material conductivity

Set DENS2 to the lower material density

Set SPHT2 to the lower material specific heat

If LOCAL is False, then initial setting of all layer thicknesses is based upon the scale of the upper material; if it is set True, the thickness of the lower layers is set by their scale.

TDAY no longer allows unstable (thin) layers, and will increase the thickness of the layer IC2 to satisfy the convergence safety factor FCONV if needed. However, the code to check on convergence was retained.

## 10.2 Setting temperature-dependant properties

Basic Flag is L10=LKOFT . If this is true, then the 8 input parameters ConUp0 to ConLo3 must be set to yield thermal conductivity as a function of temperature for the upper and lower materials.  $k = c0 + c1x + c2x^2 + c3x^3$  where  $x = (T - 200.) * 0.01$

Correspondingly, the 8 input parameters SphUp0 to SphLo3 must be set for specific heat

One way to generate the coefficients is to run for each of the upper and lower materials the IDL procedure KOFTOP, which can call all of the temperature-dependant routines. KOFTOP allows change of its parameters, including grain radius and pressure, and will print the required parameters ready for input to KRC.

Below are sample coefficients for thermal conductivity based on Sylvain Piqueux's numerical model for un-cemented soils; the fit error is  $< 0.1\%$  over 120-320K. Left column is grain radius in micrometers, then the four normalized coefficients ready for inclusion in a KRC input file, followed by the thermal inertia at 220K for nominal density and specific heat.

R(mu)	c0	c1	c2	c3	Iner
10.	0.008274	0.000735	-0.000376	0.000148	89.8
20.	0.012379	0.001280	-0.000629	0.000250	109.9
50.	0.021485	0.002647	-0.001201	0.000483	144.7
100.	0.032051	0.004528	-0.001874	0.000761	176.8
200.	0.046023	0.007569	-0.002743	0.001129	211.8
500.	0.068387	0.014075	-0.003874	0.001687	258.2
1000.	0.086303	0.021288	-0.004146	0.002099	290.1
2000.	0.103743	0.030909	-0.003141	0.002535	318.0
5000.	0.127172	0.049907	0.002019	0.003469	352.1
10000.	0.149810	0.074734	0.011546	0.004939	382.2
20000.	0.185706	0.119913	0.030938	0.007877	425.5
50000.	0.283361	0.250283	0.089327	0.016714	525.6

## 11 RUNNING THE "ONE-POINT" MODE

A parameter initialization file *Mone.inp* is provided. It sets the KRC system into a reasonable mode for one-point calculations. Do not change that file unless you have read this entire file; caveat plastes (modeler beware).

A line near the end of that file points to a file 'oneA.one' which can contain any number of one-point conditions. You can replace that name with your own; the named file is intended to be edited to contain the cases you want; however, it must maintain the input format of the sample file.

First Line is any title you wish. It must be present.

The second line is an alignment guide for the location lines. It must be there.

Each following line must start with an '11'; this is a code that tells the full-up KRC that is a one-point line. The next 9 fields are read with a fixed format, and each item should be aligned with the last character of the Column title. All items must be present, each line must extend at least to the m in Azim; comments may extend beyond that, but they will not appear in the output file. Be sure to have a <CR> at the end of the last input line; i.e., no blank lines!

The fields (after the 11) in the one-point input are:

Ls            L\_sub\_S season, in degrees

Lat	Aerographic latitude in degrees
Hour	Local time, in 1/24'ths of a Martian Day
Elev	Surface elevation (relative to a mean surface Geoid), in Km
Alb	Bolometric Albedo, dimensionless
Inerti	Thermal Inertia, in SI units
Opac	Atmospheric dust opacity in the Solar wavelength region
Slop_	Regional slope, in degrees from horizontal
Azim	Azimuth of the down-slope direction, Degrees East of North.
Title	From 1 to 20 characters, must not be entirely blank

The two additional columns in the output file are:

TkSur	Surface kinetic temperature
TbPla	Planetary bolometric brightness temperature

Try running the binary file first. If that fails, a Makefile is provided to compile and link the program; simply enter "make krc" and pray. If this fails, have your local guru look over the Makefile for local dependancies. Suggestions of making the Makefile more universal are welcome.

To run the program, change to the directory where the program was built, and enter "krc". You should get a prompt:

?\* Input file name or / for default = Mone.inp

If the initialization file still has this name and is in the same directory, enter a single "/" and <CR>. Otherwise, enter the full pathname to the initialization file, with no quotes and no blanks.

A second prompt is for the name of the output file:

?\* Print file name or / for default = krc.prt

Again, if this is satisfactory, simply enter / <CR> , else enter the desired file path-name.

### 11.0.1 Comments on the One-point model

The initialization file *Mone.inp* is a compromise between the secular trend being reached (less layers) and the annual variation being damped (more layers). The version after KRC v2.2.4 was tested over a large grid of non-polar-cap points against a model twice as deep and run for 6 years; the average absolute difference was 0.05 K. Execution time on a circa 2013 PC is about 30 cases/second.

The underlying model is the full version of KRC. By modifying the initialization file, you can compute almost anything you might want. If you choose to try this, best to read all of this document.

## 12 DEBUG OPTIONS

If the first input line has a no-zero third number, then the second line is 6 white-separated debug-control integers: IDB1 to IDB6

Most of these were converted into D-lines in v361, except the IDB2.GE.3 drint of zone table details in TDAY

```
2018 Oct 23 01:59:14 grep -in IDB *.f > qdb then grep -i idb1 qdb etc
```

```
porb08.f:16:      LOP=IDB1.GT.3
tcard8.f:128:     IF (IDB1.EQ.99) THEN 'Switching IOPM and IOERR output to IOSP'
tcard8.f:155:     IF (IDB1.GE.1) WRITE(IOPM,*)'Before PORBO'
tcard8.f:157:     IF (IDB1.GE.1) WRITE(IOPM,*)'AFTER PORBO'
tcard8.f:459:     IF (IDB1.NE.0) WRITE(IOSP,*)'TCARD Exit: IRET=',IRET,NFD,ID(1)
tseas8.f:59:      IF (IDB1.NE.0) WRITE(IOSP,*) 'TSEASa',IQ,J5,LSC,N5,LONE

tcard8.f:102:     IF (IDB2.GE.5) WRITE(IOSP,*) 'TCARD-A',IQ
tday8.f:87:      IF (IDB2.GE.5) WRITE(IOSP,*) 'TDAY IQ,J4=',IQ,J4,JJ0
tday8.f:160:     IF (IDB2.GE.3) WRITE(IOSP,*)'Zlay K J DSCAL DDZ'
tday8.f:233:     IF (IDB2.GE.3) WRITE(IOSP,',(a,2i3,6f8.3,i3,f8.4)')
tday8.f:599:     IF (IDB2.EQ.2) WRITE(IOSP,119) LZONE,LALCON,j5,IK1,IK2,IK3,IK4
tday8.f:885:     IF (IDB2.EQ.2) WRITE(IOSP,119) LZONE,LALCON,j5,IK1,IK2,IK3,IK4
tday8.f:905: 9    IF (IDB2.GE.6) WRITE(IOSP,*) 'TDAYx'
```

```

tlats8.f:52:C 2016sep09 HK Do not print T-equilb unless IDB2.ge.5
tlats8.f:129:      LQ1=IDB2.GE.5              ! once per season or latitude
tlats8.f:130:      LQ2=IDB2.GE.9              ! each time of day
tlats8.f:131:      IF (IDB2.NE.0) WRITE(IOSP,*)'TLATSa',N3,N4,J5,LATM,LQ1,LQ2
tlats8.f:274:      IF (IDB2.GE. 5) then
tlats8.f:291:      IF (IDB2.GE. 5) then
tlats8.f:647:      IF (IDB2.GE.1) WRITE(IOSP,*)' Tatm,Beta=',TATMJ,BETA
tlats8.f:667:      IF (IDB2.EQ.4) WRITE(IOPM,*)'J4,5 +',J4,J5,TEQUIL,TATMJ
tlats8.f:775: 9    IF (IDB2.GE.3) WRITE(IOSP,*)'TLATSx',N1,N1PIB,N2,N24,J3

tdisk8.f:123:      IF (IDB3.GE.3) WRITE(IOSP,31)'TDISKa',KODE,KREC,J5,K4OUT,ITOP
tdisk8.f:124:      IF (IDB3.GE.4) WRITE(IOSP,31)'TDISKb',N3,N4,N5,J5,MASE !<debug
tdisk8.f:153:      IF (IDB3 .GE. 4) THEN
tdisk8.f:162:      IF (IDB3 .GE. 4) THEN
tdisk8.f:318:      IF (IDB3.GE.3) WRITE(IOSP,*)'TDISKc KREC=',KREC,IOD2,ITOP,I
tdisk8.f:376:      IRET=IDB3 ! +1=report many values +2 report progress
tdisk8.f:393:      IF (IDB3.GE.7) WRITE(IOSP,*)'TDISKx KREC,JREC=',KREC,JREC
tfine8.f:541:      I=IDB3 ! +1=report many values +2 report progress
tlats8.f:762:      I=IDB3 ! +1=report many values +2 report progress

krc8.f:122:C- Lines are to redirect error to monitor, but IDB4 not yet known!
krc8.f:125:C-      IF (MODULO(IDB4,2) .EQ. 1) THEN ! no error file
tday8.f:389:      IF (IDB4.GE.2) WRITE(*,'(a,2I4,2f8.5,f10.3,e12.5)')
tday8.f:407:      IF (IDB4.GE.2) WRITE(IOSP,'(i3,2f12.3)') J,SCONVG(J),ZDZ(J)
tday8.f:715:D      IF (IDB4.EQ.4 .AND. MOD(JJ,NZ).EQ.0 ) ! N48 per day
tday8.f:828:D      IF (IDB4.EQ.4) WRITE(73,741)J5,J4,JJJ,-1,SNOW,EFROST,TATMJ
tlats8.f:566:C      IF (J5.EQ.IDB4) WRITE(53,531)J4,JJ,TATM,AVET,HUV ; 2018jun

tday8.f:666:      IF (IDB5.GE.4)WRITE(47,22)(TTJ(I),I=1,N1) ! coarse T
tday8.f:798:      IF (JSW.GT.0 .AND. IDB5.GE.7) WRITE(46,244)
tfine8.f:107:      IF (IDB5.GE.1) WRITE(IOSP,*) 'TFINE IQ,J4,J5=',IQ,J4,J5
tfine8.f:139:      IF (IDB5.GE.1) WRITE(IOPM,*)'QB.',QB,RLAY,RLAF,BF1,N1F,JLOW
tfine8.f:155:      IF (IDB5.GE.6) WRITE(IOPM,30),'I,j.',I,J,QB,DIFFI(I)
tfine8.f:201:      IF (IDB5.GE.1) WRITE(IOSP,'(a,i3,f12.3)')
tfine8.f:225:      IF (IRET.LT.1 .OR. IDB5.GE.2) WRITE(42,'(A,I4,2G12.5,F8.1)')
tfine8.f:340:      IF (IDB5.GE.4) THEN
tfine8.f:357:      IF (IDB5.GE.3) WRITE(IOSP,'(a,2f12.4,g13.5)')
tfine8.f:372:      IF (IDB5.GE.2) WRITE(IOSP,119) LZONE,LALCON,j5,IK1,IK2,IK3,IK4
tfine8.f:478:      IF (IDB5.GE.6 .AND. (JJ.LT.(J7P+3) .OR. ABS(JJ-J8).LT.3))
tfine8.f:515:      IF (IDB5.GE.4) THEN
tfine8.f:551: 9    IF (IDB5.GE.1) WRITE(IOSP,*) 'TFINE exit'

tfar8.f:87:      IF (IDB6.GE.2) WRITE(IOSP,*)'TFAR:0 ',KODIN,FFATE,FFOLE
tfar8.f:104:      IF (IDB6.GE.2) WRITE(IOSP,*)'TFARfile: ',FILEIN(1:ILEN),I
tfar8.f:292:      IF (IDB6.GE.4) WRITE(IOSP,*)'TFARx:FFOLE+ ',FFOLE,IFUN,LOPF
tlats8.f:187:      IF (IDB6.GT.3) WRITE(IOPM,*)'SKYFAC,FAC5X=',
tseas8:129      IF (IDB6.GE.5) WRITE(IOSP,130) I1,I2,FARTS(I1,I2,1)
about 2017      grep -in lq tlats33.f
128:      LQ1=IDB2.GE.5              ! once per season or latitude
129:      LQ2=IDB2.GE.9              ! each time of day
130:      IF (IDB2.NE.0) WRITE(IOSP,*)'TLATSa',N3,N4,J5,LATM,LQ1,LQ2
131:D      WRITE(IOPM,*)'TLATSa',N3,N4,J5,LATM,LQ1,LQ2 !<debug
175:      IF (LQ1) I=3
197:      IF (LQ1) THEN
WRITE(75,*) 'J5+',J5,SUBS,SDEC,DAU,SLOPE,SLOAZI
WRITE(75,*) 'MXX+',MXX,SKYFAC,FAC5X
241:      IF (LQ1) WRITE(IOPM,*)'TLAT1 J5,TBLOW=',J5,TBLOW

```

```

243:top of Lat loop
247:      LQ3=LD19 .AND. (J5.EQ.JDISK) .AND. (J4.EQ.1) ! first recorded season
270:      IF (LQ1) KODE=4 ! do debug print in CUBUTERP8
325:      IF (LQ1 .AND. J5.EQ.1) THEN
WRITE(75,*)'FXX+',FXX,J4,DLAT
WRITE(75,*)'QXX=',QXX
WRITE(75,*)'TXX=',TXX
WRITE(75,*)'PXX+',PXX,LPH,PARW(7),COSP
409:      IF (LQ1) WRITE(IOPM,*)'TLATS: J4+. ',J4,SOLR,ACOSLIM,COSIAM(1)
411:C3      IF (LQ3) WRITE(IOSP,701)'LQ3',NCASE,J5,J4,TATMAVE,PRES,OPACITY
431 top of time loop
529:      IF (LQ2.AND.(MOD(JJ,24).EQ.1)) THEN
WRITE(75,*)'HXX+',HXX,JJ
WRITE(75,*)'ANG:',ANGLE,COSI,COS2,DIRECT,QI
533:      IF (LQ2) WRITE(IOSP,*)', 'TLatc',JJ,COSI,COS3,DIRECT,DIFFUSE
548:C3      IF (LQ3) WRITE(88,777)JJ,COSI,COLL,HUV,QI,DIRECT,DIFFUSE,BOUNCE
551:      IF (LQ3) WRITE(88,777)JJ,COSI,COS2,AVET,HALB,DIRECT,ATMHEAT
559: end time loop
582:      IF (LQ1) WRITE (IOPM,*) 'QS, small tau=',QA,QS
602:      IF (LQ1) then
WRITE(IOPM,*)'AVEA...',AVEA,AVEE,AVEI,AVEH
WRITE(IOPM,*)'CABR...',CABR,TAUD,TAUIR,FACTOR,TAUEFF
WRITE(IOPM,*)'BETA...',BETA,QS,SIGSB
WRITE(IOPM,*)'TAEQ4,TSEQ4,TEQUIL',TAEQ4,TSEQ4,TEQUIL
618:      IF (LQ1) WRITE(IOPM,*)'TSUR,TBOT',TEQUIL,TSUR,TBOT
620:      IF (LQ1) WRITE(IOPM,*)'XCEN',XCEN
634:      IF (LQ1) WRITE(IOPM,*)'Radiation time, sec',QA
652:      IF (LQ1) WRITE(IOPM,*)'TTJ',TTJ
759: end of lat loop
761:      IF (LQ1 .AND. (.NOT. LONE) .AND. (J5.LE.1)) ! avoid line in OnePoint output
& WRITE(IOSP,*)'TLATS: TEQQ',(TEQQ(I),I=1,N4) ! starting Tequil
end lat loop

```

## 13 Accessing KRC output in IDL

IDL routines do not access files directly unless specifically listed.

DEFINEKRC Define structures in IDL that correspond for Fortran commons

Calls: None == None other than IDL library

Firm code of common definitions. Must be recoded if a Fortran \*.inc changes

KRCSIZES Compute array and common sizes for KRC Fortran

Test procedure to compute array sizes or hours.

Must recode if any size in \*.inc changes

Calls: None

READKRCCOM Read a KRCCOM structure from a bin5 file

Uses 3-element HOLD array. Returns a structure of krccom

Options to open or close bin5 file or read one case

Calls: DEFINEKRC

Files: bin5

HOLD is: 0]=logical unit 1]=number of words in a case 2]=# cases in the file

READKRC1 Read KRC direct access filesC

Calls: DEFINEKRCC

Read type -1,-2 or -3 files. Caller sets the KRC version that wrote the file.

READKRC52 Reads a KRC type 52 bin5 file

Calls: BIN5read READKRCCOM

Reads and unpacks type 52 file, returning 5 multi-dimensional arrays

KRCHANGE Find changes in KRC input values in common KRCCOM

Calls: READKRCCOM MAKEKRCVAL

Reads and stores krccom for first case. For each additional case, makes a list of any changes in the float, integer or logical input values.

KRCCOMLAB Print KRC common input items

all items via arguments

Calls: None

MAKEKRCVAL Make string of selected KRC inputs: Key=val

Calls: DEFINEKRC

KRCLAYER Compute center depth of KRC layers

all items via arguments

Calls: None

## 14 Special tabular output; routine tun8.f

Beginning with version 3.2.1, the user can request tabular output of items not in the type 52 files. This output is triggered by setting I15 to a value of 100+N where N is an option coded in the subroutine TUN8 (T unique). For each output case, there is a header line of 8 integers:

- 1: the number of dimensions to the data, Ndim, currently always 4
- 2: total number of columns in the table, 3 larger than the data columns
- 3: number of times per day output
- 4: number of latitudes
- 5: number of seasons output
- 6: IDL-style type of data for conversion, currently always 4 (single-precision floating point)
- 7: The run number in the KRC run
- 8: the case number

Thus, the first Ndim+2 values can be used to construct a storage array

This is followed by a line for every hour, latitude and season: the first 3 columns are those values as integers. The rest of the columns are [normally] floating-point values for that instant on the final convergence day of each season.

The three options coded as of 2017 Mar 2 are:

N=1: Temperatures for each layer at each hour, layer number increases to the right  
the virtual layer is omitted

N=2: Down-going solar fluxes, atmosphere and apparent sky temperatures  
floating-point columns are:

- 1: collimated insolation
- 2: diffuse and 'Bounce' insolation
- 3: Atmosphere kinetic temperature (redundant with Type 52)
- 4: Apparent zenith sky temperature:  ${}^4\sqrt{\beta} T_a$ , see [40] in the JGR KRC paper.
- 5: Effective hemispheric sky temperature:  ${}^4\sqrt{1 - e^{-\tau_r}} T_a$ , see [42]

N=3: Photometric albedoes

floating-point columns are:

- 1: time index
- 2: collimated insolation onto slope surface
- 3: all downward insolation except collimated
- 4: solar heating of atm.  $H_v$
- 5: cos of incidence angle on horizontal
- 6: current hemispheric albedo

Output is always to a file 'fort.77' in the directory where KRC was invoked, so for preservation it must be renamed before the next KRC run.

Output will be for the same set of seasons as written by TDISK. Output can be for any subset of cases in a run (single TDISK output file) or multiple runs in one input file. Output is turned on by a change line, e.g.,

2 15 101 'I15' / values to fort77

and it is turned for by, e.g.,

```
2 15 75 'I15' / RESET to no fort77
```

However, the current IDL routine to read a TUN8 output file does not accomodate cases with different sized tables.

Additional options can be coded into tun8.f .

## 15 Notes on how some aspects of the code work

Dates after some subsection titles indicate last update.

### 15.1 New file name

TCARD reads a card of Type 8, (and index is not 22 or 23)

it calls TDISK(4,0), which closes current file and sets LOPN2=.FALSE.

TCARD then moves new file name into common

KRC checks if current (new) values of N5 and JDISK call for file output;

with LOPN2=.FALSE., KRC calls CALL TDISK (1,0) to open new file.

### 15.2 End of a case and end of a run

TCARD sets KOUNT=0 at entry; this is incremented for every card except those of type 0 ( or less) or type 11 (one-point mode). When type 0 is encountered, if KOUNT is positive, does normal check of changes before return with IR=1 to indicate start of a new case; if KOUNT is zero, returns with IR=5 and prints 'END OF DATA ON INPUT UNIT'

### 15.3 Setting one-point mode

This can be done only in the first case, and there is no way to leave the one-point mode except to end the run.

TCARD encounters: " 10 \* filename" as change card in the initial case.

sets this as new input file name, then returns with IRET=4

[Thus, nothing following this change card in initial file is read]

KRC closes prior input file, opens the new one, and reads past first two lines

then calls TCARD to read first one-point line and sets LONE=true

and drops into the top of the "case" loop.

The master one-point should have a single latitude, no binary output file.

The small number of layers, days to converge, and seasons ignores the seasonal effect.

One-point request values are read by TCARD @ 310, which computes starting DJUL

TPRINT does linear interpolation of TOUT, which has N2 points be sol. To get Tp, does interpolation of Tp-Ts at the hour points, and adds to interpolated Ts.

#### 15.3.1 How one-point converts Ls to date

Ver 212: XREAD is the 2nd column in the OnePoint file, i.e., Ls.

In TCARD 310: calls PORBIT to get the date of the desired Ls, then backs up (N5-1)\*DELJUL to the starting date.

### 15.4 Starting conditions and date

Initial N5-JDISK sets the size of output files. There could be any number of interior seasons where parameter changes are made; based on successive values of IDOWN.

KRC initially calls TCARD(1

For each case loop, sets IQ=TCARD\_return. If one-point mode, sets IQ=1



TSEAS uses IQ as key. If this is 1, then sets J5=0 and sets DJU5 to season -1., else, increments J5 and increments DJU5 with current DELDUL. This allows use of variable resolution dates. (so J5 never 0 when TCARD(2) called)

TLATS uses J5 as the key; if it is  $\leq 1$ , then starts from equilibrium conditions, else uses predictions from prior season

The default is that change cards cause a fresh calculation of starting conditions. Exceptions are when J5=IDOWN > 0 at TCARD entry

## 15.5 Changing parameters within a seasonal run = Continue from memory.

When J5 reaches IDOWN, TSEAS calls TCARD, which will set IRET=3 before reading the new parameters. May change DELJUL to get finer seasonal resolution, but must NOT change N5

Use: Normal restrictions for what may not change for Type 52 files apply.

Set N5 to be the total number of seasons desired, including those after any number of parameter changes; it must NOT be changed later.

Set IDOWN to the season at the beginning of which wish to (first) change parameters. The next set of changes could include a revised (larger) IDOWN.

CAUTION: This has not been tested in recent versions

## 15.6 Use of common PORBCM

Contents are described in porbcm8.f

PORBCM is filled by TCARD calling PORB0, which reads the first 30 items in 5G15.7 from the input file and sets the value of  $\pi$  and radians-to-degrees.

TSEAS call PORBIT to get Ls, the heliocentric range and the sub-solar latitude.

## 15.7 Lower boundary condition and resetting (jumping) layer temperatures.

At the start of a case, TLATS sets the temperature profile linear with depth in one of three ways:

IIB=0: top and bottom at equilibrium temperature

IIB=1: top at equilibrium temperature, the bottom at TDEEP

IIB=2: top and bottom at TDEEP

The kind of resetting is controlled by IB. In TCARD, if IB > 0, then N1PIB=N1+1, else N1PIB=N1. T(N1+1) is not reset in the time calculations. In TDAY, for each time step, the temperature of the lower boundary is set equal to T(N1PIB), which results in either zero heat flow (IB=0) or a constant temperature.

## 15.8 Temperature scaling for KofT

TOFF and TMUL are firm-coded in tday as 220 and 0.01. These are appropriate for Mars. They may be made input parameters in later versions to address Mercury-like planets. As of v3.5.1 the scaling is firm-coded in EVMONO3D.

## 15.9 Atmosphere flag

PTOTAL is an input parameter and in KRCCOM. tseas8.f, tlats8.f, tday8.f and tfine8.f each contain: LATM=PTOTAL.GT.1. so a pressure of 1.0Pa or less is treated as zero atmosphere. The LATM flag is used liberally in those routines. tday

## 15.10 Cap-dependent pressure 2018jun22

If there is an atmosphere and more than 9 latitudes (which should be ordered from south to north), KRC will compute the global average surface frost (SUMF, kg/m<sup>2</sup>) each season by TSEAS calling TINT8; otherwise, SUMF=0. If the input KPREF is 2, then in TLATS SUMF is converted to the equivalent partial pressure and subtracted from the input total pressure.

## 15.11 Frost condensation temperature 2018jun22

The current frost condensation temperature is TFNOW (in KRCCOM). If there is an atmosphere and the LVFT input flag is false, then TFNOW is set to the TFROST input parameter; if LVFT is true, then TFNOW is reset each season and latitude using the routine GASPT based on the local current surface partial-pressure of the condensing gas (PFACTOR\*PGASG) and the two Clausius-Clapeyron input parameters. The atmospheric (cloud) condensation temperature is based on PFACTOR\*PGASG /  $e$

## 15.12 Far-field temperatures 2016jun30

FFAR initially set by KRC to be 'no'; this is less than 4 characters, so far-field is considered turned off.

An input card ' 8 3 x text': TCARD loads <text> into FFAR. For each case, KRC then checks length of FFAR; if 4 or more, will call TFAR(1 to open a FAR file for read. If successful, TFAR sets LOPN3=.true.

LOPN3 is used in TDAY as the flag that the far-field calculation is active (as opposed to self heating)

## 15.13 Seasonal variation of albedo or opacity or “climate”

When TCARD encounters a type of 8 and an index of 23(tau) [or 22(albedo)], it transfers the text item into FVTAU (which is in COMMON /FILCOM/) and then calls SEASTAU with an Ls of -999 . SEASTAU when called with LSUB LT -90 calls (providing IOD3) READTXT360, which reads file. Maximum number of rows is 360, more will be ignored. First and last entry read are wrapped with  $\pm 360$  to Ls to ensure no interpolation faults later. TCARD sets the variable Tau flag, KVTAU, to 1 if table-read was successful, else it is set to 0. If KVTAU is set to 1, TSEAS calls SEASTAU at start of each season, resetting TAUD.

If type 8 and index 23, the same as above except names are -ALB rather than -TAU

If type 8 and index 24, then TCARD calls CLIMTAU to open and read a .bin5 climate file, and sets KVTAU=2

CLIMTAU expects to read a .bin5 file (season,latitude,2) with dust and ice infrared opacities; this file is normally made by the IDL routine mopacity.pro . Season is assumed to be uniform in Ls from 0 to 360-delta and latitude assumes to be uniform from -90+delta/2 to +90-delta/2. CLIMTAU has firm-coded sizes, 72 seasons and 36 latitudes, and stores the file. Upon later calls from TLATS, it returns the two opacities at a requested Ls and latitude, using bi-linear interpolation.

## 15.14 When parameter and layer tables appear

The flag LD18 means: a value has changed after the parameter and layer tables were last are printed. It is set: initially and by TCARD. It is cleared when the tabel are printed,

Can tell if zones are active by length of FZONE in common

These two tables are printed: initially, before TSEAS for each case if LP2 is set, or after TSEAS if an error occurs or if LD15

When to print.

- first case

- if LP2 true

- if an error and prints are out of date.

  - Something is out-of-date: initially, or if TCARD was called

  - but not for each season, LSC true.

What to print

- parameters

- layers

- zones if active.

If all the prints were at the same place, or controlled from the same place, that could set the “current” flag.

As of 3.3.1,

- parameters printed by TPRINT(2

- layers printed in TDAY(3

- zones printed by READZONE in TDAY(1 or 3, if active

Because case change is done in KRC8, and errors return there with a code, the top control logic could be there.

## 15.15 Atmosphere condensation and snowfall

Each midnight, the atmospheric temperature  $T_a$  is compared to the saturation temperature  $T_{sat}$  TATMIN computed at the beginning of each season and latitude based on the two input Clausius-Calperton parameters and the partial pressure of condensable gas at one scale height above the local surface. The local surface pressure  $P_s$  (Pascal) is derived from the current 0-elevation surface pressure PZREF, the fraction of condensable gas, the local elevation and the current local scale-height SCALEH. The transfer of snow from atmosphere to ground (surface frost) is considered instantaneous. Prior to version 356, the negative energy of snow which occurs when there is no surface frost was lost from the system, but recorded as FLOST; this was rare.

The energy required to warm the atmosphere is  $E = (T_{sat} - T_a) \cdot c_a P_s / g$  where  $c_a$  is specific heat at constant pressure of the atmosphere (J/kg/K) and  $g$  the surface gravity; the terms after the dot are combined into CPOG. The snowfall amount is  $E/L_f$  (Kg/m<sup>2</sup>) where  $L_f$  is the latent heat of sublimation of frost, input parameter CFROST.

In a test with latitudes every 5° and thermal inertias of 100, 60 and 20, loss occurred on 3.5% of the snowy days with a average loss of 0.63 kg/m<sup>2</sup>, equivalent to 3.7E5 J/m<sup>2</sup>. The top physical layer in these models was 3.0, 1.8, and 0.6 kg/m<sup>2</sup>, respectively, so they would be cooled by 190, 320, and 960 K, far greater than needed to reach frost temperature.

Thus, beginning in version 3.5.6, the snow is assumed to become surface frost and the surface set to frost temperature.

## 15.16 Seasonal prediction Update 2020apr11

Several quantities are stored in TDAY at midnight; with index J3P1: TT1,TTS, TTB, and if Atm., TTA,FRO. These are effectively at the start of day J3+1. Index 1 is set initially as the global equilibrium T.; after season 1, these are set to the prediction from the prior season. After convergence, TLATS uses EPRED to predict these to the end of the season.

355 and earlier ALERT: TTA,FRO not set for index 1.

Up to version 355:

JE is the index of the first (of three) midnight given to EPRED

FP is the number of sols forward to predict.

Normally JE is J3P1-2 == J3-1

If the prediction is less than 0.1 sol, use force EPRED into linear mode.

Version 356: The full daily time series for a season is passed to EPRED, along with the index of the last valid value. If 3 or more points valid, does asymptotic predict limited by the latest slope, there is no minimum FP. Else, if 2 points valid, does linear predication; else, uses the last valid value.

Outline of code:

- For each latitude, if the first season, TTJ is set linear with depth between TSUR and TBOT; which in turn depend upon how IIB is set; otherwise start with forecast for the last midnight of the prior season.
- TDAY runs until convergence, saving the profile each midnight.
- For each layer, the temperatures at midnight are forecast to the end of the season.

Annotated code extracts:

```
daycom:: TTJ(MAXN1P)          ! Layer temperatures (TTJ(1) is surface temperature)
          TT1(MAXN1,MAXN3)    ! Temperatures at start of day for each layer and day
latcom:: TMN4(MAXN1,MAXN4) ! predicted convergence midnight temperature
```

Line in TLATS [2020 Apr 11 17:39:42]

```
before TDAY
642. (J5.LE.1): CALL MVD(TTJ,TT1,N1) ! temperature profile, start of first day
660. else:      CALL MVD(TMN4(1,J4),TT1,N1PIB) ! copy forecast midnight values
667. CALL TDAY
715. I=1,N1
      CALL MV21D (TT1(I,1),MAXN1,WORK,J3P1) ! transfer all defined values for layer I
      TMN4(I,J4)= EPRED8(WORK,FP,J3P1, TFNOW,TBLOW) ! forecast to end of season
```

## 16 Non-standard FORTRAN

All thought to be removed in Version 3+

Although the SAVE option is used in some routines, this has not been done for all routines that depend upon values being consistent between successive calls, so “-fno-automatic” must be invoked in the Makefile.

## 16.1 Modifying size parameters

Most arrays are sized using PARAMETER's set in krcc8m.f. Hopefully, these could be modified without breaking the KRC system. If you do so, extensive testing is recommended.

In particular, if a user were generating jillions of direct access files, it would be efficient to set MAXN4 and MAXNH to the values of N4 and N24; however, their product must be larger than the size of KRCCOM (NWKRC), or twice as large if writing single-precision files. In version 3.6.1 there is a test for this, which will STOP if the condition is violated.

## A Map of type 52 file

Type 52 is a "bin5" file; this has an ASCII header followed by a N-dimensional binary array whose dimensions and word-type are defined in the header; for type 52, the number of dimensions is 5 and the type is REAL\*4 or REAL\*8. The 4th dimension is increased to allow room for a "prefix" to be embedded in the binary array for each case.

The array is written by the tdisk[8] routine, which stores values for each season for each case in the large buffer FFF.

Type 52 = (N24 hours, 7 items, N4 latitudes, NDX+seasons, cases)

The 7 items are:

- 1)=TSF Final hourly surface temperature
- 2)=TPF Final hourly planetary temperature
- 3)=TAF Final hourly atmosphere temperature, not predicted
- 4)=DOWNVIS Hourly net downward solar flux [W/m<sup>2</sup>]
- 5)=DOWNNIR Hourly net downward thermal flux [W/m<sup>2</sup>]
- 6) packed with:
  - NDJ4 Number of days to compute solution
  - DTM4 RMS temperature change on last day
  - TTA4 Predicted final atmosphere temperature
  - TIN(2:n) Minimum hourly layer temperature, starting with first real layer
    - n is the smaller of: N1 (the number KRC computed
    - N24-2 (limit of what fits in this file)
- 7) packed with:
  - FROST4 Predicted frost amount, [kg/m<sup>2</sup>]
  - AFRO4 Frost albedo (at the last time step)
  - HEATMM Mean upward heat flow into soil surface on last day, [W/m<sup>2</sup>]
  - This would have contributed to sublime frost-cap if it were present
  - TAX(2:n) Maximum hourly layer temperature. Parallel to TIN

Type 52 allows multiple cases, each with a "prefix" for each case stored in the NDX leading extra seasons. This region contains:

4 integers (converted to Real) that define sizes

- (1)=FLOAT(NWKRC) Number of 4-byte words in KRCCOM, currently 255
- (2)=FLOAT(IDX) 1-based index of the dimension with extra values
- (3)=FLOAT(NDX) Number of those extra
- (4)=FLOAT(NSOUT) Number of output seasons (Not used; could be redefined)

followed by KRCCOM, defined in krccom.inc or krccom8.f

followed by a sub-array (seasons,5) (0-based index)

- 0]=DJU5 Current Julian date (offset from J2000.0)
- 1]=SUBS Seasonal longitude of Sun, in degrees
- 2]=PZREF Current surface pressure at 0 elevation, [Pascal]
- 3]=TAUD Mean visible opacity of dust, solar wavelengths

If a climate model is used, value if for the last latitude.  
4]=SUMF Global average columnar mass of frost [kg /m<sup>2</sup>] (If computed)

Thus the prefix requires NPREF = [255 or 426]+4 +5\*nseas words;  
where nseas is the number of seasons output: NJ5-JDISK+1

Each season contains N24\*7\*N4 words, the number of leading pseudo-seasons is  
NDX = Ceil ( NPREF / (N24\*7\*N4) )

For Type 52, the size of a case is set by the first case. The number of cases allowed is set by this size and printed as MASE at the end of the first case in the print output.

KRC input items that would change any of the bin5 dimensions are not allowed to increase between cases; i.e., N24, N4 and nseas=N5-JDISK. An invalid change of these will be detected in tdisk.f; a note will go to the print file and the error file, the output file will be written with any cases completed up to this point and the file closed. All remaining cases will be computed but not saved.

The number of cases that can be stored is dynamic and fairly liberal; recent versions of KRC reserve 10 M words for the bin5 array. So, for example, with N24=24, 19 latitudes and 50 stored seasons, up to 61 cases can be saved in one run.

In the IDL readkrc52 routine, these are expanded into 5 arrays and a structure. The dimensions here are typical; produced in krcvtest @188

```
TTT          FLOAT      = Array[24, 5, 3, 120, 8]
(hour,item,latitude,season,case)
itemt = Tsurf, Tplan, Tatm, DownVIS, DownIR
```

```
DDD          FLOAT      = Array[21, 2, 3, 120, 8]
(layer,item,latitude,season,case)
itemd = Tmin, Tmax
```

```
GGG          FLOAT      = Array[6, 3, 120, 8]
(item,latitude,season,case)
itemg = NDJ4, DTM4, TTA4, FROST4, AFRO4,, HEATMM
```

```
UUU          FLOAT      = Array[3, 2, 8]
(nlat,item,case)      Values often the same for each case
itemu = Lat., elev
```

```
VVV          FLOAT      = Array[120, 5, 8]
(season,item,case)    First 2 item values often the same for each case
itemv = DJU5, SUBS, PZREF, TAUD, SUMF
```

KRCCOM is in kcom: readkrc52 returns values for the first case  
\*\* Structure <cdcab8>, 7 tags, length=1020, data length=1020, refs=1:

```
FD          FLOAT      Array[96]
ID          LONG       Array[40]
LD          LONG       Array[20]
TIT         BYTE       Array[80]
DAYTIM      BYTE       Array[20]
ALAT        FLOAT      Array[37]
ELEV        FLOAT      Array[37]
```

For the REAL\*8 version, the order is changed

FD	REAL*8	Array[96]
ALAT	REAL*8	Array[37]
ELEV	REAL*8	Array[37]
ID	LONG	Array[40]
LD	LONG	Array[20]
TIT	BYTE	Array[80]
DAYTIM	BYTE	Array[20]

## B Time-step doubling

In the JGR article, a convergence safety factor is defined as  $B_i/\sqrt{2\Delta t_i \cdot \kappa_i}$  ; KRC[103]. In the code, the square of this,  $B_i^2/(2\Delta t_i \cdot \kappa_i)$  is defined as SCONVG and printed.

Proceeding from the top, if SCONVG is more than twice CONVF for a layer, then the time-step can be doubled for that layer.

Code changed significantly when layer tables added; between

v321: layer thickness BLAY set by FLAY (virtual) and RLAY  
and 331: BLAY set by FLAY (top physical) and RLAY

With zone table, at each layer must know the minimum pre-doubling safty factor at all lower layer

For same layer thicknesses, after first time doubling, 321 and 341 converg. factor disagree!

### B.1 Version 343

Code includes several loops for setting layer parameters, starting at the indicated line number ( 2016 sept 5 source code):

Set the thermophysical properties for each layer. Seperate exclusive loops for

156: zone table or not.

278: no zone table

327: Print temperature-dependent properties for up to two zones

369: If not a zone table, check lower material stabilty and increase layer thickness if needed.

379: LOOP 1 compute safety factor for each layer before any doubling SCONVG(J)

387: LOOP 2. Find the minimum safety factor at or below each layer before any time doubling; ZDZ (temporary)

406 LOOP 3 Assign time doubling, from top to depth. In English:

IF: have not yet reach maximum number of time doublings allowed

AND at least 2 physical layers already

AND number of time steps now is even

AND new time-step would be acceptably stable for all lower layers

THEN, do doubling at current layer and update forecast factor.

436: Generate the last-layer versus time comb KJ

480: Print the layer table

### B.2 TDISK called by

```
krc8.f:228: IF (.NOT.LOPN2 .AND. I.GE.4) CALL TDISK8 (1,0) ! open output disk file
tcard8.f:137: CALL TDISK8 (1,1) ! open old file to read starting conditions
```

```
tday8.f:902: IF (J5.GE.JDISK) CALL TDISK8(2,I) ! write current season if valid
tseas8.f:169: IF (J5.GE.JDISK) CALL TDISK8 (2,KREC) ! write this season
```

```
tcard8.f:138: CALL TDISK8 (3,KOLD) ! read starting record; will override KRCCOM
```

```
krc8.f:231: IF (.NOT.LOPN4 .AND. I.GE.4) CALL TDISK8 (6,0) ! open output type 5x
```

```

krc8.f:313:  IF (LOPN2) CALL TDISK8 (4,KREC) ! close FDIRA, cannot hold multiple cases
krc8.f:334:  IF (LOPN2) CALL TDISK8 (4,KREC) ! all done: close disk files
tcard8.f:263: IF (LOPN2) CALL TDISK8 (4,0)    ! close prior direct-access file
tcard8.f:310: IF (LOPN2) CALL TDISK8 (4,0)    ! must close disk files if open
tcard8.f:140:          CALL TDISK8 (4,0)      ! close 'starting' file

tseas8.f:168: .AND. K4OUT.LT.0) CALL TDISK8 (5,KREC) ! must follow tday(1)

krc8.f:231:  IF (.NOT.LOPN4 .AND. I.GE.4) CALL TDISK8 (6,0) ! open output type 5x

krc8.f:337:  IF (LOPN4) CALL TDISK8 (7,KREC) ! type 5x
tcard8.f:258: IF (LOPN4) CALL TDISK8 (7,0)    ! close current bin5
tcard8.f:312: IF (LOPN4) CALL TDISK8 (7,0)

```