

# 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, (2012) [Ref. 1]

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

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

### 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 **PROGRAM** [,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**

## 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); 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 depths 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.

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

Delta-Eddington model for insolation; direct onto sloped surface and diffuse, with possible twilight extension. Atmosphere temperature based on Delta-Eddington solar absorption 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) by the PORB code set.

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

Options:

- Different Physical properties below a set layer (IC).
- Regional slope
- Three ways to handle seasonal global pressure variation

Atmosphere condensation:

- Global integral of CO2 frost-gas budget can control surface pressure.
- 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.

## 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  $(X(N1))^2/2$ , 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

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 for Mars orientation and orbit in 2010, and should not be touched; they can be replaced by running PORBMN carefully.

The title lines are skipped, so that you may 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 will read next card as 6 debug flags, IDB1 to IBD6, which are normally zero. See §10 below

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

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.

Items with numbers inset 2 spaces below are computed, not input. The source code for 'krccom.inc' indicates which subroutine sets many of the parameters; as the routine name in lowercase just below the parameter name.

- - - - -

Type 4 Title (20A4) 80 characters of anything to appear at top of each page.

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 [J/(kg K)] {cal/(g K) * 4184.}
8  DENS   Surface density [kg/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 unused      [Phase of ABRAMP, degrees relative to midnight]
12 PTOTAL Global annual mean surface pressure at 0 elev., Pascal[=.01mb]
           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 IB>=1.
16 SPHT2  Lower material specific heat (IC>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 asymmetry factor
           moon = eclipse start time in local Hours
22 ARC3   unused      [coeff. for planetary heating]
           moon = eclipse duration in seconds 0=no eclipse
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 [J/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. [kg/m^2]
           the greater of this and 0.01 is always used.
32 fd32   unused
- - - - -
    Thermal Solution Parameters
33 RLAY   Layer thickness ratio
34 FLAY   First 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 DDT    Convergence limit of temperature RMS 2nd differences
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)

```

```

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 Applied Optics 1977 v.16, p.2693: 1367.9 W/m^2
    1366.2 Based on figure in Frohlich, Observations of
    irradiance variations, Space Sci. Rev.,94,15-24,2000
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*4 values
65 HUGE = 3.3E38 nearly largest REAL*4 value
66 TINY = 2.0E-38 nearly smallest REAL*4 value
67 EXPMIN = 86.80 neg exponent that would almost cause underflow
68 FSPARE Spare
69 FLOST Atm frost 'lost' in the atm. in last day at current lat./season
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 TAEFF 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) =====

```

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=19). 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  IB      Bottom control: 0=insulating, 1=constant temperature
           2=start all layers =TDEEP & constant temperature
8  IC      First layer (remember that 1 is air) of changed properties.
           if 3 to N1-2. > N1-2 (e.g., 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. 0=none
13 IDOWN   Season at which to read change cards
14 I14     Index in FD of flexible print
15 I15     ""
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;
           0=KRCCOM,LATCOM each season
           1:49=KRCCOM,DAYCOM for the last latitude; each season
           Modes of bin5 file for multiple cases
           51=(Hours, 2 min/max, lat, seasons, cases)
           52=(hours, 7 items, lat, seasons, cases)
           54=[many seasons, 5 items,lats, cases]
           55=[many seasons,9 items, cases]
           56=[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 to print notice
- - - - -

```

Computed I\*4 values

```

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(4) spare
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 JJ0     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)
3  LP3      Print hourly conditions on last day (3)
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     Read change item from terminal after main input set
13 LSC      Read change cards from input file at start of each season
14 LNOTIF   spare
15 LOCAL    Use each layer for scaling depth
16 LD16     Print hourly table to fort.76 [TLATS]
17 LPTAVE   Print <T>-<TSUR> at midnight for each layer [TDAY]
18 LD18     spare
19 LD19     Output to fort.79 [TLATS] insolation and atm.rad. arrays
20 LONE     (Computed) Set TRUE if KRC is in the "one-point" mode
- - - - -

```

followed in 'krccom' by:

```

[real*4] TITLE(20) 80-character title
[real*4] DAYTIM(5) 20-character run  date and time
=====

```

Latitude(s) (10F7.2) N4 latitudes in degrees, no internal separations.  
 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 PORBCM.INC

## 4 PARAMETER CHANGES

Fortran List Directed. Change the values in KRCCOM White-separated, 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
2	Integer Parameter	1:NIDR
3	Logical Parameter	1:NLDR
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 disk or season-variation file name 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	
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	

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

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 hokey technique of using a bad 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 Tau 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.

## 5 Contents of COMMOMS

COMMON /KRCCOM/ Input and transfer variables. See krccom.inc

COMMON /DAYCOM/ Layer and time-of-day items. See daycom.inc



COMMON /FILCOM/ File names. See filcom.inc  
COMMON /HATCOM/ Store post-2003 items. See hatcom.inc  
COMMON /LATCOM/ Latitude-dependent items. See latcom.inc  
COMMON /PORBCM/ PORB system geometry matrix. See porbcm.inc  
COMMON /UNITS/ Logical units for I/O and errors. See units.inc

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/hkierfer/krc/src [replace top part of path with local installation]
rm allinc.txt
cat krccom.inc latcom.inc daycom.inc hatcom.inc filcom.inc units.inc porbcm.inc > allinc.txt
```

## 6 Error Returns

### 6.1 Tday Blowup

There are two triggers:

(ADELN.GT.0.8):  $\frac{|\Delta T|}{T} > 0.8$

(TSUR.GT.TBLOW):  $t_{\text{blow}} = \frac{\langle S \rangle}{\epsilon \sigma}$

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.

### 6.2 Other errors: INCOMPLETE

"Parameter error in TDAY(1)" : Convergence factor < .8 classic.

Instability anticipated.

"UNSTABLE; Layer..... TDAY(1):

```
DRSET: 0=>      Reset by delta_average_T for each layer:
                  else: reset by {linear + DRSET*quadratic}*{<surf>-<botm>}
TDAY: LRESET    Reset midnight T's for all but top layer.
      LDAY      Last day computations
```

## 7 DISK BINARY FILES

The routine TDISK is used to read or write direct-access binary files or bin5 files. The first season to write is specified by JDISK, all following seasons will go to the same file. For direct-access files, each file record consists of KRCCOM plus LATCOM or KRCCOM plus DAYCOM.

Disk output is largely controlled by the KRC and TSEAS routines.

### 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 JJJJJ 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 record content:

- Will output first record of KRCCOM,ALAT,ELEV, then records of TSF & TPF
- 0 Will output records of KRCCOM+LATCOM. Usual for large data-base.
- +n<=50 Will output records of KRCCOM+DAYCOM for the last computed latitude.

>50 Will write custom bin5 file at the end of a run, with dimensionality from 3 to 5 (more possible). All 5x outputs allow 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. KRC input items that would change any of the bin5 dimensions are not allowed to change between cases. Each dimension is adjusted to the necessary size. Each case has the same structure; this simplifies coding although some items are then present redundantly. 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.

The first 4 words of the prefix, and of 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]

51=(N24 hours, 2: TSF TPF, 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

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

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,AFRO4,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 prefix is identical to Type 51

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 51

```

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 larger than needed.

## 8 Handy things

The first "hour" in printout and output arrays is 1/24 (strictly, 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 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

```

### 8.1 ASCII Output Files

krc.prt General results. Stuff output is controlled by LP1:6 & LPGLOB

fort.76

```

tlat.f: mimic Mike Mellon ASCII files
      if (ld16) then
        write(76,761)subs,dlat,alb,skrc,taud,pres
761    format(/,'      Ls      Lt      A      I      TauD      P'
762    format(f7.2,f9.3,f8.3,f9.3)
        write(76,762)qh,tsfh(i),adgr(j),qs

        do i=1,n24
          j=(i*n2)/n24
          qh=i*qhs
          qs=(1.-alb)*asol(j) ! absorbed insolation
          write(76,762)qh,tsfh(i),adgr(j),qs
        enddo

```

fort.78

```

tlat.f: for average and maximum:
      if (ld18) write(78,*)cosi_(i), t_(i),ADGs(i),ADGP(i)
      if (ld18) write(78,*)j5,j4,sol,ave_a,adgir,c52,beta

```

```

fort.79
tlats.f:  for each time-step
          if (ld19) write(79,*)adgr(jj),qa,direct,diffuse
          col 1 = downgoing thermal radiation
          col 2 = total insolation reaching surface
          col 3 = direct fraction of insolation
          col 4 = diffuse fraction of insolation

```

## 8.2 To run two material types

Set IC to the first layer to have the lower material properties (  $i = 3$  )

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 IC to satisfy the convergence safety factor FCONV if needed. However, the code to check on convergence was retained.

## 8.3 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

## 9 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.

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.

### 9.0.1 Comments on the One-point model

The initialization file *Mone.inp* is set to compute the temperatures at the season requested without seasonal memory. It uses layers that extend to 5 diurnal skin depths. It does not treat the seasonal frost properly, so don't believe the results near the edge of the polar cap. Execution time on a circa 2001 PC may be the order of 0.01 seconds per case.

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.

## 10 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

```
tcard.f:75:      IF (IDB2.GE.5) WRITE(IOSP,*) 'TCARD-A',IQ
tcard.f:123:     IF (IDB1.GE.1) PRINT *,'Before PORBO'
tcard.f:125:     IF (IDB1.GE.1) PRINT *,'AFTER PORBO'
```

```

tcard.f:349:    IF (IDB1.NE.0) WRITE(IOSP,*)'TCARD Exit: IRET=',IRET,NFD,ID(1)
tday.f:63:     IF (IDB2.GE.5) WRITE(IOSP,*) 'TDAY IQ,J4=',IQ,J4,jjo
tday.f:544: 9   IF (IDB2.GE.6) WRITE(IOSP,*) 'TDAYx'
tdisk.f:90:   IF (IDB3.NE.0) WRITE(IOSP,*)'TDISKa ',KODE,KREC,NCASE,J5,K4OUT
tdisk.f:424:   IF (IDB3.GE.3) WRITE(IOSP,*)'TDISKc KREC=',KREC,LOPN2,IOD2,I
tdisk.f:431:   IF (IDB3.GE.3) WRITE(IOSP,*)'TDISKx KREC=',KREC
tlats.f:56:   LQ1=IDB2.GE.3           ! once per season or latitude
tlats.f:+    LQ2=IDB2.GE.6           ! each day
tlats.f:+    IF (IDB2.NE.0) WRITE(IOSP,*)'TLATSa',N3,N4,J5,LATM,LQ1,LQ2
tlats.f:422: 9   IF (IDB2.GE.3) WRITE(IOSP,*)'TLATSx',N1,N1PIB,N2,N24,J3
tseas.f:41:   IF (IDB1.NE.0) WRITE(IOSP,*)'MSEASa',IQ,IR,J5,LSC,N5,LONE
in tlats.f:
  98: IF (LQ1) THEN
    WRITE(75,*) 'J5+',J5,SUBS,SLOPE,SLOAZI,SKYFAC
    WRITE(75,*) 'MXX+',MXX,DIP,SAZ
    WRITE(75,*) 'PXX+',PXX
top of Lat loop
130:   IF (LQ1) PRINT *,'TLAT1 J5,TBLOW=',J5,TBLOW
170: IF (LQ1) THEN
    WRITE(75,*)'FXX+',FXX,J4,DLAT
    WRITE(75,*)'RXX=',RXX ! R should be 90 deg from F
    WRITE(75,*)'TXX=',TXX
221:   IF (LQ1) print *,'TLATS: J4,SOLR...',J4,SOLR,ACOSLIM,COSIAM(1)
top of time loop
299:   IF (LQ1.AND.(MOD(JJ,24).EQ.1)) THEN
    WRITE(75,*)'HXX+',HXX,JJ
    WRITE(75,*)'ANG:',ANGLE,COSI,COS2,DIRECT,QI
303:   IF (LQ2) WRITE(IOSP,*)',TLatc',JJ,COSI,COS3,DIRECT,DIFFUSE
309:   IF (LD19) WRITE(79,777) QA,QI,DIRECT,DIFFUSE,BOUNCE
end time loop
341:   IF (LQ1) then
    PRINT *,'AVEA ...',AVEA,AVEE,AVEI,AVEH
    PRINT *,'CABR...',CABR,TAUD,TAUIR,FACTOR,TAUEFF
    PRINT *,'BETA...',BETA,QS,SIGSB
    PRINT *,'TAEQ4,TSEQ4,TEQUIL',TAEQ4,TSEQ4,TEQUIL
356:   IF (LQ1) PRINT *,'TSUR,TBOT',TEQUIL,TSUR,TBOT
    IF (LQ1) PRINT *,'XCEN',XCEN
379:   IF (LQ1) PRINT *,'TTJ',TTJ
453:   IF (LD16) THEN
    WRITE(76,761)SUBS,DLAT,ALB,SKRC,TAUD,PRES
    loop on hour: WRITE(76,762)QH,TSFH(I),ADGR(J),QS,TPFH(I)
end lat loop

```

Set LD19 to write bottom-of-atmosphere downgoing fluxes to separate file for every time-step for every latitude, every time tlats is called.

## 11 Reading type 5x files

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

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

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

### 12.1 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.

### 12.2 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'

### 12.3 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 between sol. To get Tp, does interpolation of Tp-Ts at the hour points, and adds to interpolated Ts.

### 12.3.1 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.

## 12.4 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)

If J5 equals IDISK2, then TSEAS calls TCARD(2 to read changes, and proceeds to next season.

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

## 12.5 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 5x files apply. E.g., type 56 must NOT change number of latitudes nor total number of seasons.

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.

## 12.6 Use of common PORBCM

Contents are described in porbcm.inc

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. KRC references porbcm.inc but does not use it.

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

## 12.7 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:

IB=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.



## 12.8 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

## 12.9 No atmosphere flag

**tseas.f** contains: LATM=PTOTAL.GT.1. so a pressure of 1.0Pa or less is treated as zero atmosphere. The LATM flag is used only in **tlats** and **tday**

## 12.10 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, true if table-read was successful, else it is set false. If KVTAU is set, 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.

## 12.11 Cap-dependent pressure

```
TSEAS:  BUF(1)=0.          ! flag for TINT to compute areas
IF (N4.GT.8) CALL TINT (FROST4, BUF, SUMF)
```

Tlats

```
IF (N4.GT.8) THEN          ! use global integrations
  PCAP = SUMF*GRAV         ! cap_frost equivalent surface pressure
```

```
KPREF.EQ.2
```

```
PZREF = PTOTAL - PCAP
```

```
PCO2G = PCO2M -PCAP ! all changes are pure CO2
```