Design and Use of the KRC Thermal Model

Hugh H. Kieffer

Celestial Reasonings

hkieffer@charter.net

775-782-0767

Observe temperatures, but commonly want physical properties. Connected by a model. **$I=\sqrt{(k\rho C)}$ = Thermal Inertia**

- **K=k= conductivity**
- **R=rho = ρ=density**
- **C= specific heat**

- **Basic temperature response to a periodic radiation boundary condition**

Required reading: JGR-Planets 2013

Thermal model for analysis of Mars infrared mapping

Purpose: Transfer knowledge of KRC

- A. Users of the maintained version on website: krc.mars.asu.edu
- B. Folks wanting their own copy: at ASU or elsewhere
- C. People wishing to modify KRC at their site
- D. Curation staff:
  - Cognizant programmer
  - Mentor
  - Website master

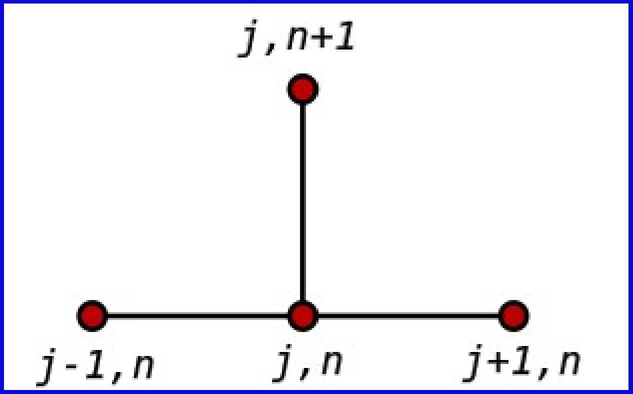
– Documentation is not always reliable. Search the code

Outline

- A brief history of a long time
- Physics included and omitted
- Input format: normal and OnePoint
- Examples
- Architecture
  - Run, case, season, latitude, day, time-step, layer
  - Call Diagrams: Flow between routines
- Use of Commons
- Output formats: Print and binary
  - Sequential Access: 3 each
  - .bin5 packed: 5 each
- PORB: Objects other than Mars
- Liens: Things yet to be done
- [[Typical Use: Model Sets; detailed studies

History

- Begun in 1968 to support Mariner 6 and 7 infrared radiometers (IRR) and proposal for Viking IRTM
- Anticipated need for global/annual models == big runs
- Computers were much slower than today
  - One case: 18 latitudes, 40 seasons, took an hour on the fastest unclassified computer in the world.
  - Now, one second
- Choose implicit forward differences
- Carefully code for speed
- Evolution: step-wise, with occasional bug fixes
  - Physics-based one-layer atmosphere
  - Additional output formats
  - Temperature-dependent thermal conductivity and specific heat



^ Time

Depth ->

Major physics

- **Upper and lower materials: separate K, ρ, C**
- **K and C may be temperature-dependent; cubic polynomial in T**
- **Terrain can slope, or be bottom of conical pit**
- **Insulating or fixed T lower boundary**
- **Any orbit, spin axis, rotation period.**
- **One layer atmosphere, gray in solar and thermal regions. Or none**
- **Atmosphere radiation, but not conduction.**
    - **Conserves energy**
    - **Local seasonal condensation.   Atm. condensation falls as snow**
- **If surface reaches CO_2 saturation, starts frost accumulation**
    - **Switch to frost properties; gradual for albedo**
    - **Total frost may control global pressure, (the only latitude coupling)**
        - **or use Viking Lander relation, or constant**
- **Allows table-driven seasonal opacity and albedo**
    - **Can use seasonal map of dust and ice opacity**
        - **Version derived from Mike Smith THEMIS maps available**
- **Allows twilight**

Basic Surface and Subsurface Treatment

- Surface condition: Radiation Balance
  - Specify albedo A , emissivity ε, slope and azimuth.
  - Can have frost with different A, ε and scattering thickness scale
  - Frost albedo: constant or linear with insolation (two precoded)
  - Imbalance of solar and thermal radiation goes into changing temperature of the top layer, or into changes of frost amount.
- Subsurface: thermal diffusion
  - Specify thermal inertia (I), conductivity(k) and density(ρ)
  - Lower boundary can be insulating, constant temperature, or fixed constant.
  - Can have a different material below a given layer;

    k, ρ and specific heat C_P.

Atmosphere and multiple scattering

- Gray in solar and thermal region, one layer,
  - Transmits, absorbs, and scatters solar radiation; Two stream Delta-Eddington
  - Transmits, absorbs and emits thermal radiation, Isotropic
  - Flux imbalance goes into change of temperature (apart from twilight)
- Dust amount and radiative characteristics can be specified
- Direct sunlight: Lambertian local surface -> DIRECT
- Diffuse Vis. & IR: based on fraction of sky visible -> DIFFUSE
- Reflected from surface -> BOUNCE
- All three Vis. above normalized to solar flux at Mars -> SOLR
- Surface pressure based on elevation. one of:
  - constant,
  - follow Viking Landers
  - based on global integration of frost.

2-stream Delta-Eddington for Sunlight

- f tp://climate1.gsfc.nasa.gov/wiscombe/Multiple_Scatt/DeltaEddington/DeltaEddingPaper.pdf
- Joseph et al, 1976 Delta-Eddington Approximation for radiative flux transfer,J.Atm.Sci vol.33,2453-2459 (1976)
- deding2.f See citations therein. Comments tie equations.
- Collimated and diffuse beams
- Scattering uses Henyey-Greestein function.
  - Assymetry set by ARC2 -> G0
    - Zero is isotropic, + 1 is pure forward scattering
  - Single scattering albedo set by DUSTA -> OMEGA . Maximum 0.999
- Runs in double precision (required)

Method

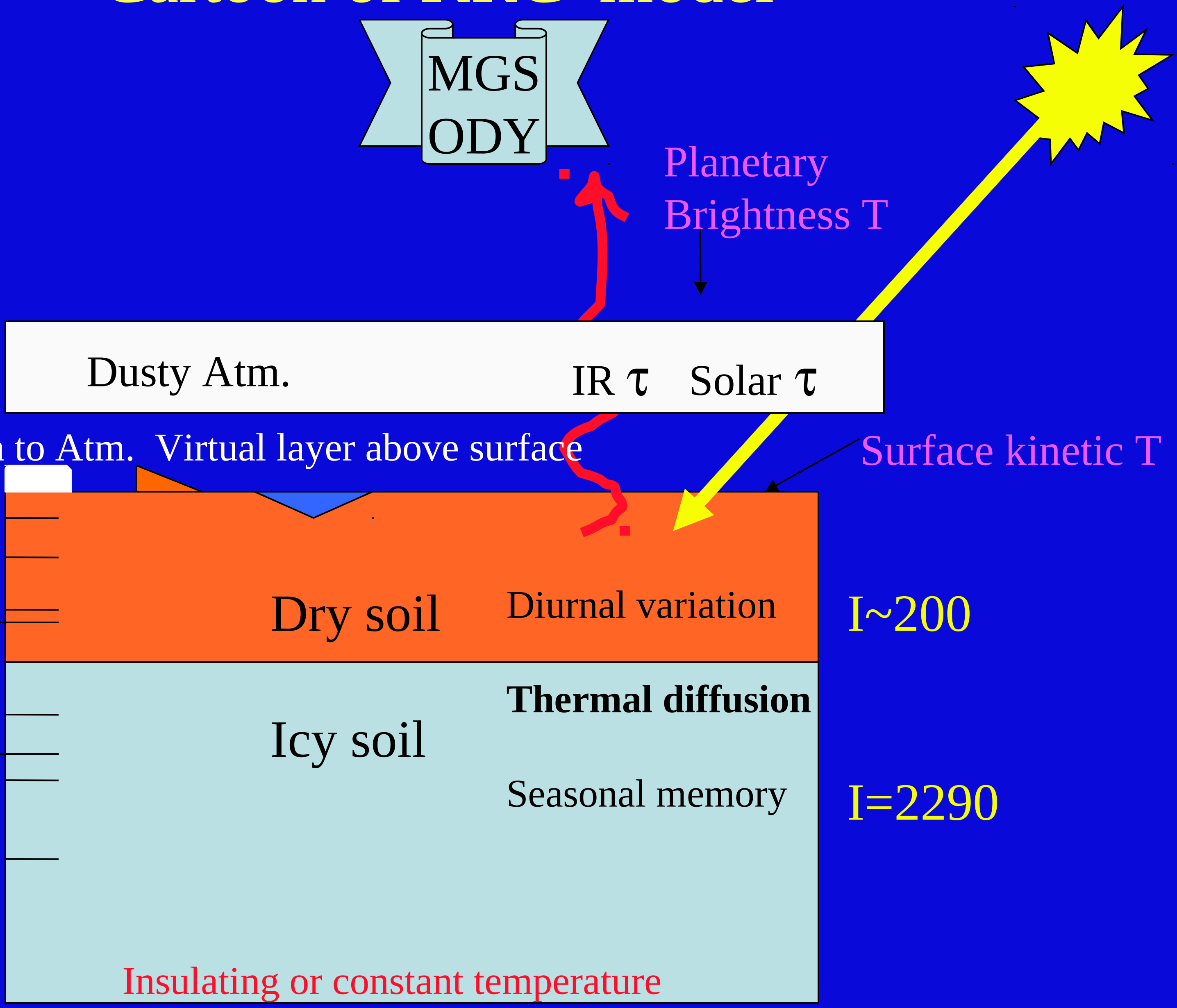
- Surface thermal inertia, specific heat and density determine the conductivity and diffusivity. Layers scaled with the diurnal skin depth (DSD)
  - First layer is 0.18 of DSD, successive ones thicker by factor of 1.2
  - As layers become so thick that thermal diffusion through them is small in one time step, time steps are doubled
  - Elaborate start-up and convergence techniques; Stability tests

This scheme allows accurate practical treatment of diurnal and seasonal heat flow

Virtually all physical and grid parameters adjustable: ~127 total.

Most you need not touch.

Cartoon of KRC model



MGS
ODY

Planetary
Brightness T

P varies with season
and elevation

Dusty Atm.

IR τ Solar τ

No conduction to Atm. Virtual layer above surface

Surface kinetic T

Frost
Slopes and pits

Dry soil

Diurnal variation

I~200

Option for
T-dependent
Conductivity
and
Specific heat

Icy soil

Thermal diffusion

Seasonal memory

I=2290

Insulating or constant temperature

What is in KRC

- Periodic insolation (sunlight)
  - Brightness of the Sun (or any star)
  - Orbit of mars (or any other elliptical orbit)
  - Orientation of Mars spin axis (or any planet/satellite/asteroid)
  - Length of a “day” (Sun on the meridian)
  - Any number of seasons/year, up to many years
- Up to 37 latitudes in a set. All with the same properties
- Up to two layered materials; any total depth
  - Density (constant), thermal conductivity, specific heat (may vary with T)
- Surface albedo; flat, plane slope, or conical depression
- Second-order dusty/icy atmosphere, or no atmosphere

- What's not included

Absent Geophysics. To be included?

- Radiative-convective atmosphere (Jakosky-Mellon)
- Turbulent mixing (Need wind speed; Vasavada; GCM)
- More than 2 materials; fully-flexible layer structure
- Vertical transport of sensible and latent heat by gaseous diffusion (Mellon, others) and regolith breathing (no one?)
- Local rocks and shadows: *lateral heat conduction*
- Regional topography with *shadows and radiative coupling*
- Season changes incrementally every SOL
  - Now: Planet spins in place for a season
- Geothermal heat flow
- Solar eclipse (for satellites)
- Equation of time (length of solar day varies through a year)

Atmosphere model.

- **One Layer, gray in solar and thermal.**
- **Delta-Eddington, two-stream**
- **Starts at equilibrium with surface based on diurnal average radiation balance.**
- **Solar heating plus any infrared excess or deficit: change the temperature**
- **Affects view-from-space bolometric temperature**

Slopes and pits

- **Considers direct, diffuse, and one-bounce radiation.**
- **Approximation: regional surrounds at same temperature as target.**

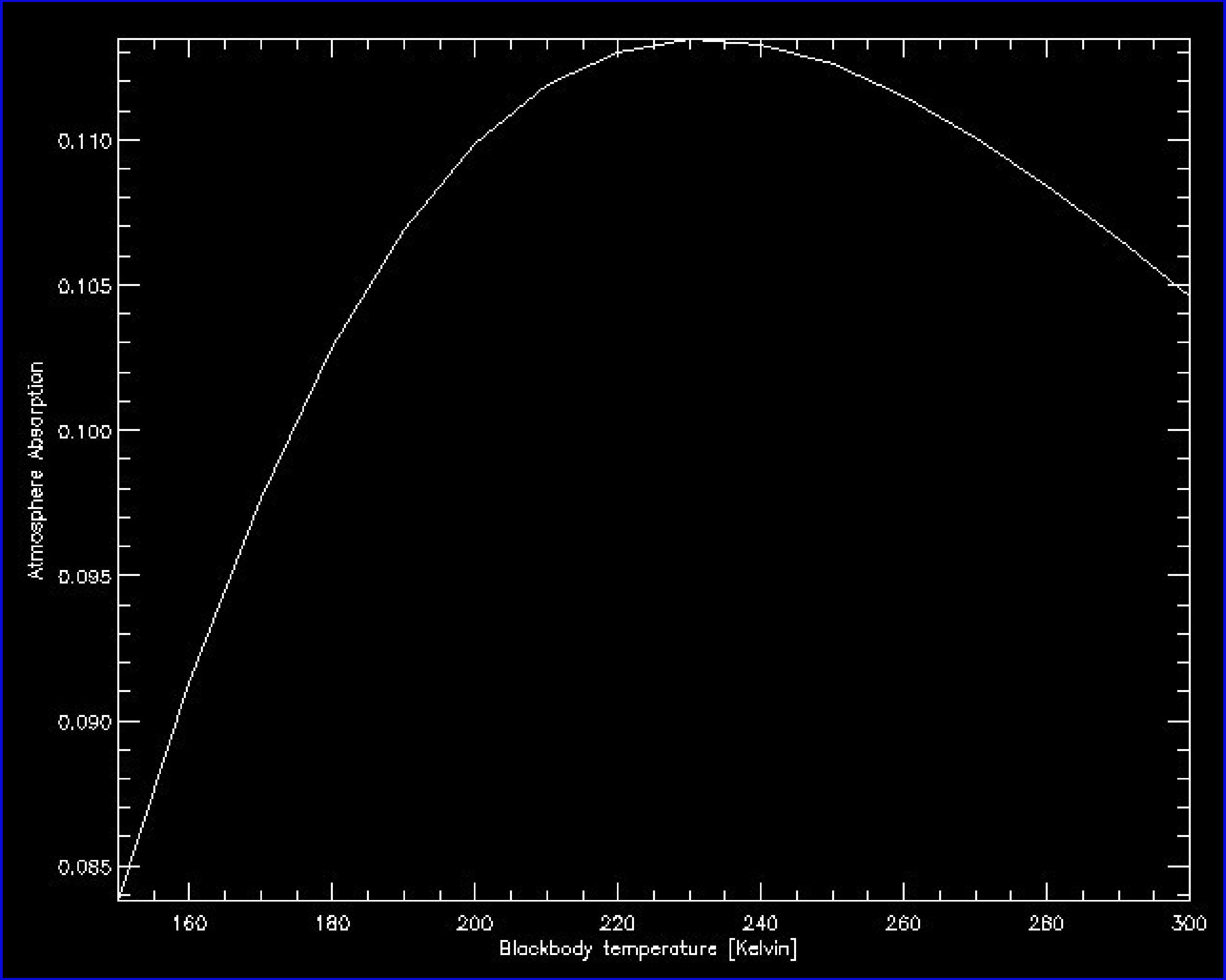
KRC atmosphere

- One layer; solar and thermal radiation (later slide)
- Gravity and molecular weight: default to Mars
- Set the scale height

$$P \propto e^{-z/\mathcal{H}} \quad \text{AND} \quad \mathcal{H} = T_a \mathcal{R}/\mathcal{M}g$$

- Surface pressure: 3 options
  - Constant, $\propto$Viking, decreased by global frost mass.
- Dust opacity may vary with season: scaled to local pressure
- Global table, or zonal climate that allows ice-cloud opacity
  - Ice-cloud opacity does not scale to local surface pressure
- One-component may condense: snow and accumulated mass
- Presence of any frost sets surface T at the local saturation value
  - Frost albedo may vary with insolation intensity (Mars' does)
  - Frost effect on albedo goes realistically to zero as it thins

CO2 gas only thermal radiation absorption



Energy Balance & Heat Diffusion Equations

Surface energy balance; excess/deficit into frost

$$W = (1. - A)S'_{(t)} + \Omega\epsilon R_{\Downarrow} + k\frac{\partial T}{\partial z}_{(z=0)} - \Omega\epsilon\sigma T^4$$

Subsurface: $$\frac{\partial T}{\partial t} = \frac{-1}{\rho c}\frac{\partial}{\partial z}\left(-k\frac{\partial T}{\partial z}\right) = \frac{k}{\rho c}\frac{\partial^2 T}{\partial z^2} + \left[\frac{1}{\rho c}\frac{\partial k}{\partial z}\frac{\partial T}{\partial z}\right]$$

Last term
assumed
zero

Finite
difference
code for grid

$$\frac{\Delta T_i}{\Delta t} = \frac{2}{B_i\rho_i C_i}\left[\frac{T_+ - T_i}{\frac{B_i}{k_i}+\frac{B_+}{k_+}} - \frac{T_i - T_-}{\frac{B_i}{k_i}+\frac{B_-}{k_-}}\right]$$

T-dependent
properties

Coded for T-ind as: `DO J=2,KN` with KN a “comb” for time-steps

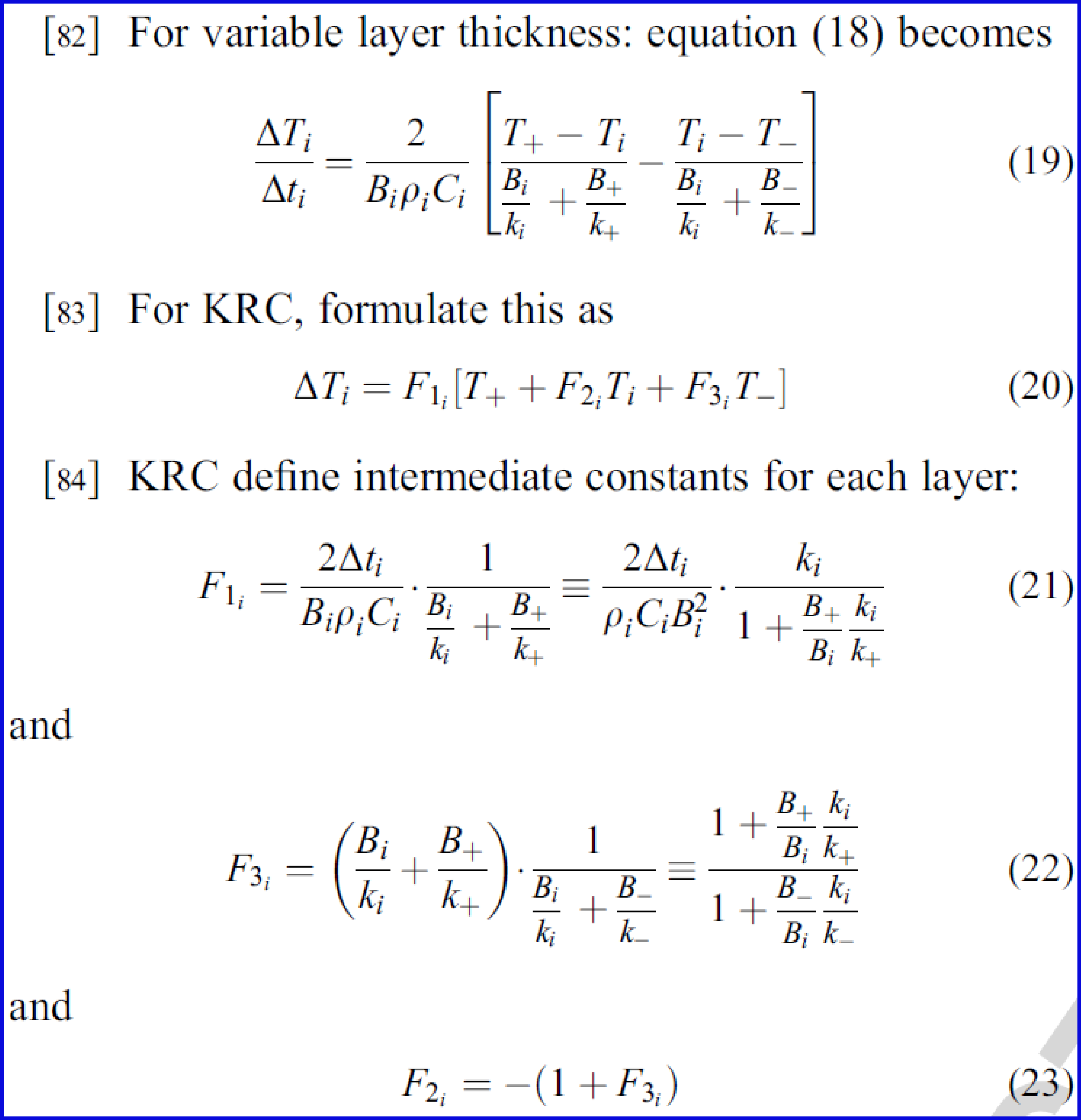
```
DTJ(J)=FA1(J)* (TTJ(J+1)+FA2(J)*TTJ(J)+FA3(J)*TTJ(J-1))
```

Much more code for the T-dep case.

Followed by:

```
DO  J=2,KN
     TTJ(J)=TTJ(J) + DTJ(J)
```

Equations accomodating T-dependence



[82] For variable layer thickness: equation (18) becomes

$$\frac{\Delta T_i}{\Delta t_i} = \frac{2}{B_i \rho_i C_i}\left[\frac{T_+ - T_i}{\frac{B_i}{k_i} + \frac{B_+}{k_+}} - \frac{T_i - T_-}{\frac{B_i}{k_i} + \frac{B_-}{k_-}}\right] \tag{19}$$

[83] For KRC, formulate this as

$$\Delta T_i = F_{1_i}[T_+ + F_{2_i}T_i + F_{3_i}T_-] \tag{20}$$

[84] KRC define intermediate constants for each layer:

$$F_{1_i} = \frac{2\Delta t_i}{B_i \rho_i C_i} \cdot \frac{1}{\frac{B_i}{k_i} + \frac{B_+}{k_+}} \equiv \frac{2\Delta t_i}{\rho_i C_i B_i^2} \cdot \frac{k_i}{1 + \frac{B_+}{B_i}\frac{k_i}{k_+}} \tag{21}$$

and

$$F_{3_i} = \left(\frac{B_i}{k_i} + \frac{B_+}{k_+}\right) \cdot \frac{1}{\frac{B_i}{k_i} + \frac{B_-}{k_-}} \equiv \frac{1 + \frac{B_+}{B_i}\frac{k_i}{k_+}}{1 + \frac{B_-}{B_i}\frac{k_i}{k_-}} \tag{22}$$

and

$$F_{2_i} = -(1 + F_{3_i}) \tag{23}$$

- For T-dependence, must evaluate all k for each time-step.
- For T-ind, in each equation the B and k terms reduce to a single constant value for each layer

More Equations

Convergence criterion

$$\frac{\Delta t}{(\Delta Z)^2}\kappa < \frac{1}{2} \quad \text{or} \quad (\Delta z)^2 \equiv B^2 > 2\Delta t\kappa$$

Two-stream
Delta-Eddington

$$F = \pi * \left[I_0 \pm \tfrac{2}{3} I_1\right]$$

where + is down, $F^{\downarrow}$; - is up, $F^{\uparrow}$

Atmospheric heating

$$H_V = S_M * \left(\mu_0 - F^{\uparrow}(0) - (1 - A_s)\left[\mu_0 \mathrm{COLL} + F^{\downarrow}(\tau)\right]\right)$$

$$H_R = \epsilon\sigma T_s^4(1. - e^{-\tau_e}) - 2R_{\Downarrow t} \quad = \quad \sigma\beta_e(\epsilon T_s^4 - 2T_a^4)$$

$$\frac{\partial T_a}{\partial t} = \frac{H_R + H_V}{c_p M_a}$$

Planetary Temperature

$$\sigma T_P^4 = \epsilon\sigma T_S^4(e^{-\tau_R}) + \sigma T_a^4(1 - e^{-\tau_R}) \quad \text{or} \quad T_P = \left[\epsilon(1. - \beta)T_S^4 + \beta T_a^4\right]^{1/4}$$

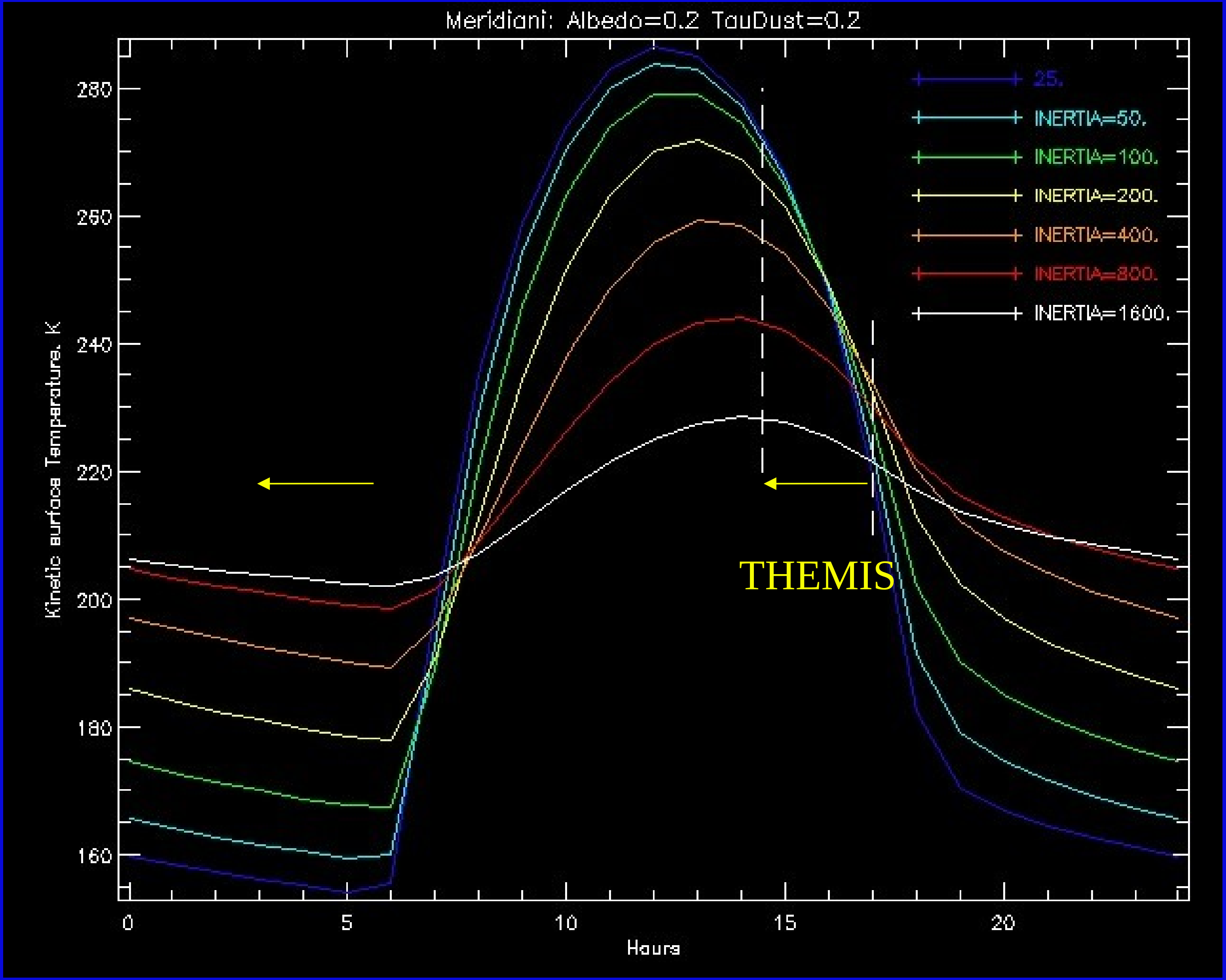
Numerical Approach

- **Explicit forward finite differences**
- **Highly optimized code**
- ***Basic loop architecture***
- **[Cases]**
  - **Seasons**
    - **Latitudes**
      - **Days**
        - **Layers-1**
        - **Layers-2**
- **Up to 30 layers, up to 37 latitudes, up to 384*4 time-steps per sol, output at 24 or 48 “hours”/day, up to 16 days to converge., up to 740 seasons.**
  - **All the maximum sizes could be adjusted in krccom.inc**

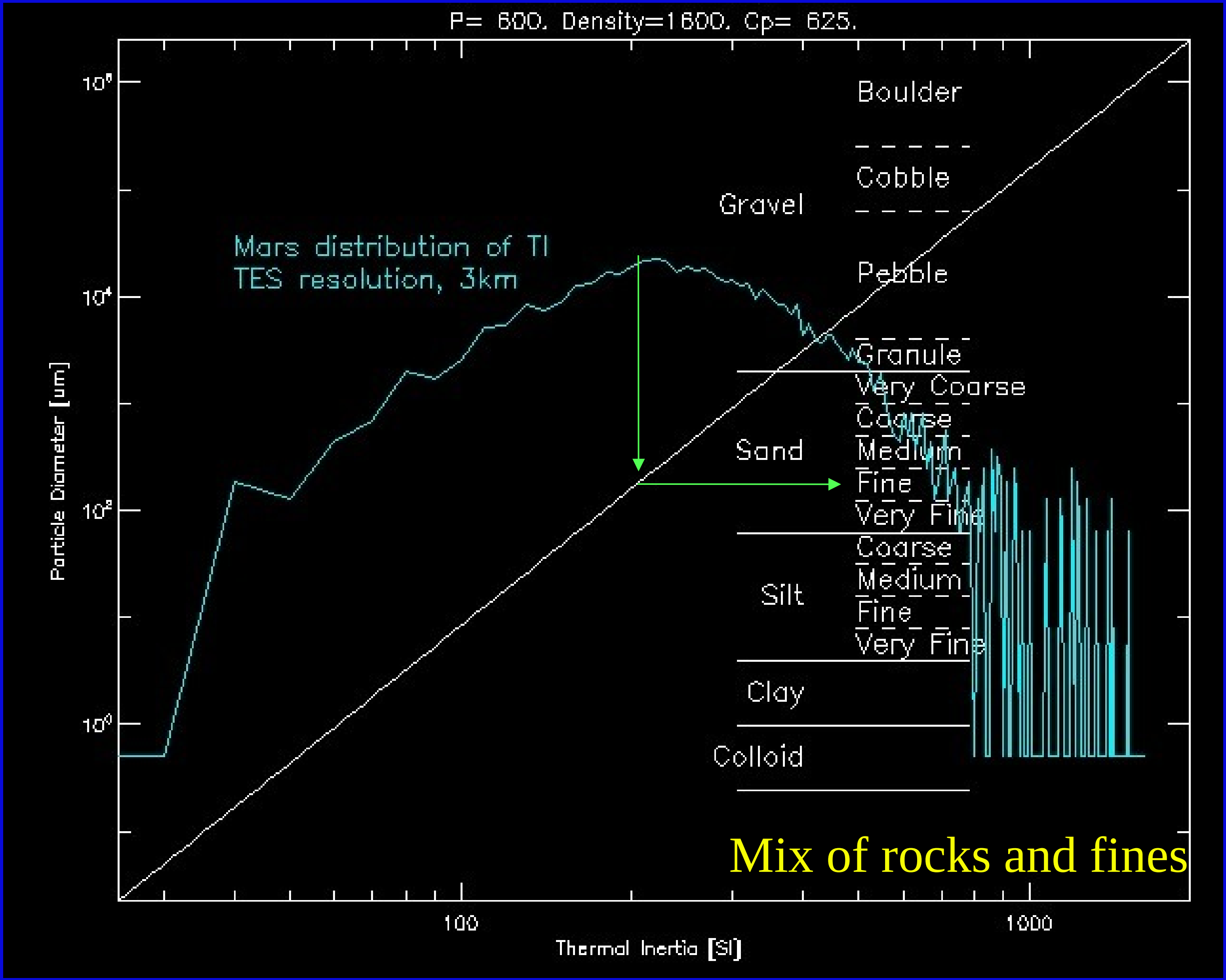
- **Dynamic dimensioning of .bin5 output files [not FORTRAN-friendly]:**

  e.g., latitudes*seasons*cases

Thermal inertia effect on temperature



Effective particle size on Mars



Mix of rocks and fines

Frost and snow

- Local seasonal CO_2 saturation at surface
- Super-cooling of atmosphere avoided: energy supplied by CO_2 condensation.
- Resulting snow falls to surface (within a day) and adds to surface frost inventory.
- Surface frost albedo can follow observed insolation-dependence
  - Mars' seasonal frost albedo commonly increases with Sun intensity
- Thin frosts are translucent, no discontinuities !
- Global integration of solid CO_2 :
  - average mass deducted from surface pressure

How close is KRC to Mars ???

- KRC based on best-estimates of physical parameters
- Absence of wind-effect probably the largest shortfall.
- Beware working near the edge of the seasonal cap:
  - Interpolation commonly not valid between frost and no-frost

Everything controlled by input file

- # layers, Hours_out/day, latitudes, seasons,…
- Start date, Delta season, first to disk, index of major changes
- Surface physical properties: two materials
- neither/both use T-dependent properties
- Atmosphere properties
- Frost physical and radiative prop.
  - Option: insolation dependant albedo
- Planet orientation, day and orbit
  - Pre-computer rotation matrices
- Layer and time scheme; Convergence criteria
- Print output
- Output files: 3 direct-read (FORTRAN sequential access)
- and 5 compound .bin5
  - Most users will be fine with Type 52

Meant to be a tool: Many ways to use it

- **Sets of uniform global models**
  - **E.g., Viking used three**
  - **THEMIS using hundreds**
  - **Global average temperature map used nearly a thousand**
- **Studies of slope effect**
- **Models of rock proportion**

- **Multi-year "spin-up" , then every sol, hour or time step (5 minutes)**

- **The "one-point" mode:**
- Input list of targets:
- Phil ran 1.5 billion points to make thermal movie

- There is a "Helplist" users guide

- KRC website provides ability to run the maintained version
- A distribution includes all source code, sample files, documentation,…

What do You want to do?

Several output formats: e.g. Type 52 has:

- **Surface kinetic, planetary and atmosphere temperatures every “Hour”,**
- **minimum and maximum diurnal temperatures for each layer,**

For each latitude:

Days to convergence, RMS temperature change on last day,
predicted atmosphere temperature, amount of frost, frost albedo,
mean upward heat flow into surface

Global values for every season:

Julian date (offset from 2,440,000), Ls, Atm pressure at 0 elevation,
dust opacity, total frost.

IDL readers provided for every output format.

Need to generate a common-language (non-IDL) reader

There is a DeVinci input interface to prior KRC version; could easily be updated

Input File: it’s simpler than it looks

master.inp 2013jan22

```
 0 0 / KOLD: season to start with;  KEEP: continue saving data in same disk file
Default values for all parameters. 19 latitudes with mean Mars elevations
    ALBEDO     EMISS   INERTIA     COND2     DENS2    PERIOD SPEC_HEAT   DENSITY
       .25      1.00     200.0      2.77     928.0    1.0275      647.     1600.
      CABR       AMW   [ABRPHA    PTOTAL     FANON      TATM     TDEEP   SpHeat2
      0.11      43.5     -0.00     546.0      .055      200.     180.0     1711.
      TAUD     DUSTA    TAURAT     TWILI      ACR2     [ARC3     SLOPE    SLOAZI
       0.3       .90       0.5       0.0       0.5     -0.00       0.0       90.
    TFROST    CFROST    AFROST     FEMIS       AF1       AF2    FROEXT     [FD32
     146.0   589944.       .65      0.95      0.54    0.0009       50.       0.0
      RLAY      FLAY     CONVF     DEPTH     DRSET       DDT       GGT     DTMAX
    1.2000     .1800    2.0000       0.0       0.0     .0020       0.1       0.1
      DJUL    DELJUL  SOLARDEC       DAU     LsubS    SOLCON      GRAV     AtmCp
  10322.33   17.1745      00.0     1.465        .0     1368.     3.727     735.9
    ConUp0    ConUp1    ConUp2    ConUp3    ConLo0    ConLo1    ConLo2    ConLo3
  0.050087 -0.002145  0.002347 -0.000750  2.766722 -1.298966  0.629224 -0.527291
    SphUp0    SphUp1    SphUp2    SphUp3    SphLo0    SphLo1    SphLo2    SphLo3
  646.6275  246.6678  -49.8216    7.9520  1710.648  721.8740  57.44873  24.37532
        N1        N2        N3        N4        N5       N24        IB        IC
        20       384        15        19       120        24         0         7
     NRSET      NMHA      NRUN     JDISK     IDOWN    FlxP14    FlxP15     KPREF
         3        24         1        81         0        45        65         1
     K4OUT     JBARE     Notif   [IDISK2                                     end
        52         0        20        -0                                       0
    LP1    LP2    LP3    LP4    LP5    LP6 LPGLOB   LVFA   LVFT  Lkoft
      F      T      F      F      F      F      F      F      F      F
  LPORB   LKEY    LSC  spare  LOCAL  Prt76 LPTAVE  Prt78  Prt79  L_ONE
      T      F      F      F      T      F      F      F      F      F
```

Input file, continued

```
Latitudes: in 10F7.2  _____7 _____7 _____7 _____7 _____7 _____7 _____7
 -87.50 -80.00 -70.00 -60.00 -50.00 -40.00 -30.00 -20.00 -10.00   0.00
  10.00  20.00  30.00  40.00  50.00  60.00  70.00  80.00  87.50  -0.00
Elevations: in 10F7.2 _____7 _____7 _____7 _____7 _____7 _____7 _____7
   3.51   2.01   1.39   1.22   0.38   0.48   1.17   1.67   1.26   0.17
  -0.94  -1.28  -1.99  -2.51  -3.52  -4.08  -4.51  -4.38  -2.57  -0.00
  08 Sep 29 10:41:33 =RUNTIME.  IPLAN AND TC=   4.0 0.55000
   4.000000      0.5500000      0.8650615      0.3229325E-01   5.000821
  0.9340634E-01   1.523671       12882.95       686.9650      0.9229904
   5.544495       24.62280       0.000000      0.4093198       0.000000
   0.000000       0.000000       0.000000       6.159676      0.4662921
  0.4172604E-01  0.6197483       4.381073       0.000000       1.228627
  0.6619807       0.000000       1.391099      0.1075499     -0.3195100E-01
  0.2263214      -1.246176      -0.5861457     -0.8611114E-01  0.8908045
  0.4461527     -0.9063585      0.1158813     -0.4063075     -0.4136413
 -0.4393618      0.7974096      0.9138050     -0.4049719     -0.3095386E-01
  0.4054090      0.9140893      0.9184200E-02  0.2457525E-01 -0.2094154E-01
  0.9994786     -0.3252879     -0.8556869     -0.4024770      0.9456150
 -0.2943530     -0.1384504      0.7823110E-07  0.4256245     -0.9048999
8 0 0 '/work1/krc/mars/masterA.t52' / Disk file name
1 12 540.  'PTOTAL set to yield 7  mb at VL1 @ Ls=100' /
1 4 0.22 'COND2'/  to match lower k(T)
1 35 4. 'CONVF' / push time doubling start deeper
0/                  a zero ends a case
3 10 1 'LkofT' / Temperature-dependant conductivity
0/
0/   two zeros end a run
```

Locations

Orbit and Pole matrix. Mars 2005

Change Cards, See Helplist

Input Changes

2 integers, 1 real/integer/logical, one text [/] free comments

```
8 0 0 '/work1/krc/mars/master.t52' / Disk file name
1 12 540.  'PTOTAL set to yield 7  mb at VL1 @ Ls=100'
1 35 4. 'CONVF' / push time doubling start deeper
0/   <<< end of a case
0/   <<< 2nd consecutive 0 is end of the run
```

Next is an example of an elaborate set of change cards that looks in detail at the temperatures through the first 40 sols of ice freshly exposed at the bottom of a conical pit. It uses 3 latitudes and does 5 cases; the first is ice freshly exposed to a full hemisphere of sky, followed by pits with slopes of 45 and 25 degrees, then these two pits with a different initial ice temperature

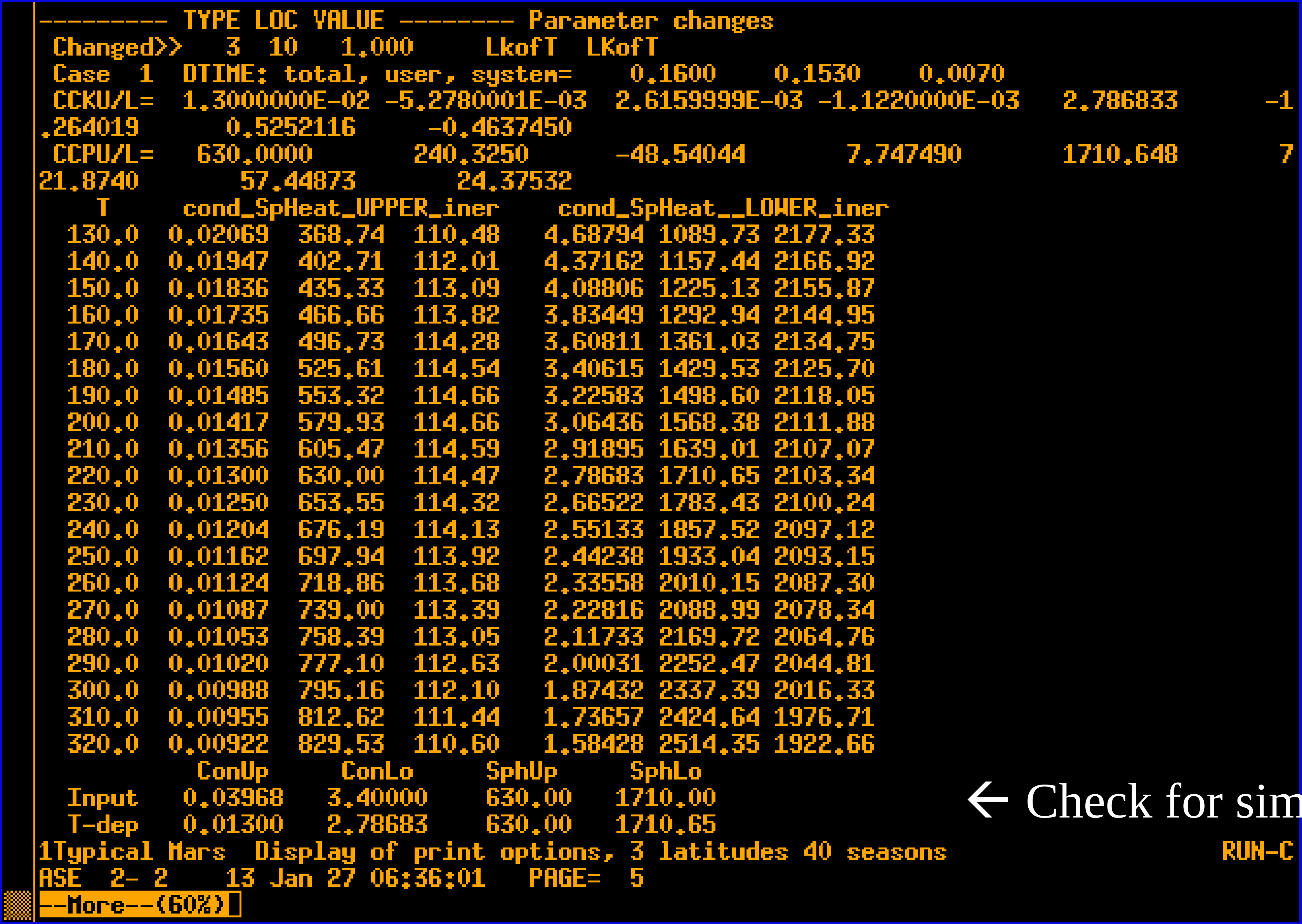
Complex Input

```
7 7 7 'Pit dug to ice by Phoenix' / New title
8 0 0 '../output/phx4.t52' / Disk file name/
1  1 .20 'Albedo'
1  3 2025.3 'Inertia for ice' /
1  7 1300.  'Spec heat' / for ice
1  8 928. 'Density' / for ice
1 15 185. 'TDEEP' /
1 17 0.2 'TAUD'
1 39 .001 'GGT: set to avoid ending early' / set for daily output
1 41 11920.2 'DJUL' / starting date
1 42 1.0275 'DELJUL  1 sol' / set for daily output
2  1 19 'Num Layers' /
2  3 1  'N3: set to run each day' / set for daily output
2  4 3  'N4' / number of latitudes
2  5 40 'N5' /  total number of seasons = sols
2  7 2  'IB start all =TDEEP' /
2 12 1  'JDISK start immediately' /
2 17 52 'K4OUT’ /
4 77 77 'New Latitudes' / Must be N4 of them in  10F7.2
  65.00  70.00  72.00 -10.00   0.00  10.00  25.00  45.00  70.00  22.00
5 77 77 'New Elevations' / Must be N4 of them in  10F7.2
   -3.5   -3.5   -3.5   00.0   00.0   00.0   00.0   00.0   00.0   -3.1
0/
1 24 -400. 'Azimuth. Set flag to indicate  a pit' /
1 23 45. 'Slope' / slope of pit wall
0/
1 23 65. 'Slope' /
0/
1 23 45. ’reset Slope' /
1 15 220. ' TDEEP' /
0/
1 23 65. 'Slope' /
0/
0/
```

Layer Table: I=200 Cp=630 Density=1600

```
 Conductiv.= 3.968E-02  Dens*Cp= 1.008E+06  Diffu.= 3.937E-08  Scale= 3.335E-02
          ___THICKNESS____    ________CENTER_DEPTH_____ CONVERGENCE
  LAYER      scale     meter      scale     meter      kg/m^2  factor
     1     0.1800    0.0060    -0.0900   -0.0030      0.000   0.000
     2     0.2160    0.0072     0.1080    0.0036     11.527   2.851
     3     0.2592    0.0086     0.3456    0.0115     25.359   2.053
     4     0.3110    0.0104     0.6307    0.0210     41.958   2.956
     5     0.3732    0.0124     0.9729    0.0324     61.877   2.129
     6     0.4479    0.0149     1.3834    0.0461     85.779   3.065
     7     0.5375    0.0179     1.8761    0.0626    114.462   2.207
     8     0.6450    0.0215     2.4673    0.0823    148.882   3.178
     9     0.7740    0.0258     3.1768    0.1060    190.185   2.288
    10     0.9288    0.0310     4.0282    0.1344    239.749   3.295
    11     1.1145    0.0372     5.0498    0.1684    299.226   2.372
    12     1.3374    0.0446     6.2758    0.2093    370.598   3.416
    13     1.6049    0.0535     7.7469    0.2584    456.244   2.460
    14     1.9259    0.0642     9.5123    0.3173    559.020   3.542
    15     2.3111    0.0771    11.6308    0.3879    682.351   2.550
    16     2.7733    0.0925    14.1730    0.4727    830.348   3.672
    17     3.3279    0.1110    17.2235    0.5745   1007.945   5.288
    18     3.9935    0.1332    20.8843    0.6966   1221.061   7.615
    19     4.7922    0.1598    25.2771    0.8431   1476.800  10.965
    20     5.7506    0.1918    30.5485    1.0189   1783.687  15.790
    21     6.9008    0.2302    36.8742    1.2299   2151.951  22.737
    22     8.2809    0.2762    44.4651    1.4831   2593.868  32.742
    23     9.9371    0.3314    53.5741    1.7869   3124.169  47.148
    24    11.9245    0.3977    64.5049    2.1515   3760.530  67.893
    25    14.3094    0.4773    77.6219    2.5890   4524.163  97.766
  Bottom layers for time doubling:        2    4    6    8   10   12   14   25
```

T-dependent Table



```
---------- TYPE LOC VALUE --------- Parameter changes
 Changed>>   3  10   1.000     LkofT  LKofT
 Case  1  DTIME: total, user, system=    0.1600     0.1530     0.0070
 CCKU/L=  1.3000000E-02 -5.2780001E-03  2.6159999E-03 -1.1220000E-03   2.786833       -1
.264019      0.5252116     -0.4637450
 CCPU/L=   630.0000        240.3250       -48.54044        7.747490        1710.648        7
21.8740       57.44873        24.37532
     T      cond_SpHeat_UPPER_iner     cond_SpHeat__LOWER_iner
  130.0  0.02069  368.74  110.48   4.68794 1089.73 2177.33
  140.0  0.01947  402.71  112.01   4.37162 1157.44 2166.92
  150.0  0.01836  435.33  113.09   4.08806 1225.13 2155.87
  160.0  0.01735  466.66  113.82   3.83449 1292.94 2144.95
  170.0  0.01643  496.73  114.28   3.60811 1361.03 2134.75
  180.0  0.01560  525.61  114.54   3.40615 1429.53 2125.70
  190.0  0.01485  553.32  114.66   3.22583 1498.60 2118.05
  200.0  0.01417  579.93  114.66   3.06436 1568.38 2111.88
  210.0  0.01356  605.47  114.59   2.91895 1639.01 2107.07
  220.0  0.01300  630.00  114.47   2.78683 1710.65 2103.34
  230.0  0.01250  653.55  114.32   2.66522 1783.43 2100.24
  240.0  0.01204  676.19  114.13   2.55133 1857.52 2097.12
  250.0  0.01162  697.94  113.92   2.44238 1933.04 2093.15
  260.0  0.01124  718.86  113.68   2.33558 2010.15 2087.30
  270.0  0.01087  739.00  113.39   2.22816 2088.99 2078.34
  280.0  0.01053  758.39  113.05   2.11733 2169.72 2064.76
  290.0  0.01020  777.10  112.63   2.00031 2252.47 2044.81
  300.0  0.00988  795.16  112.10   1.87432 2337.39 2016.33
  310.0  0.00955  812.62  111.44   1.73657 2424.64 1976.71
  320.0  0.00922  829.53  110.60   1.58428 2514.35 1922.66
             ConUp      ConLo      SphUp      SphLo
  Input    0.03968    3.40000    630.00    1710.00
  T-dep    0.01300    2.78683    630.00    1710.65
1Typical Mars  Display of print options, 3 latitudes 40 seasons                    RUN-C
ASE   2- 2    13 Jan 27 06:36:01    PAGE=   5
--More--(60%)
```

← Check for similarity

The one-point mode

- **Input file points to ‘one.inp’ list of “targets”.**
- **Interactive, or provide a text-file of rows with**
  - **Ls = season**
  - **Latitude**
  - **Hour of day**
  - **Surface elevation**
  - **Albedo**
  - **Thermal Inertia**
  - **Solar opacity**
  - **Surface slope**
  - **Slope azimuth**
- **Any other non-default values can be specified in the formatted input parameter file**
- **Outputs:**
  - **Surface kinetic temperature**
  - **Top-of-atmosphere bolometric brightness temperature**

KRC-lite. The "one-point" interface

- You build a table of "points" of interest:
  - Ls
  - Latitude
  - Hour
  - Elevation (km)
  - Bolometric Albedo
  - Thermal Inertia (SI units)
  - Atmosphere Visual opacity
  - Regional slope (degrees)
  - Azimuth of down-slope (degrees Eastward of North)
- Output file has these, plus columns of:
  - Surface kinetic temperature, Tsurf
  - Top-of-Atmosphere bolometric temperature,Tplan==Tbolo

One-point details

- Copy one.inp Edit it; rigid format. Keep name the same
  - Title Line, Text transfered to output. This & next line must be present
  - 11 Ls Lat Hour Elev Alb Inerti Opac Slop_Azim <Align each field
  - 11 123.1 4.1 9.4 22.22 0.17 100.0 0.10 0 0
  - 11 320.1 -33.1 15.5 -3.12 0.15 500.1 0.55 0.0 123.
  - 11 180. -10.1 13.5 0. 0.20 200.0 0.50 0.0 123.

- Run krc. Input file is: krcone_master.inp
  - This file sets KRC into 13 layer, 1 latitude, short season mode, and points to one.inp.

- Underneath the one-point mode is the full KRC model

- You can copy krcone_master.inp and edit it to do [almost] whatever you like, including point to a different one-point file

Production Mode

- Pre-compute hundreds of models on a grid of albedo, dust opacity, thermal inertia, surface elevation, latitude, hour, season.

  Traditionally output direct-access files, a record for each season

- Interpolation scheme: mostly quadratic
- Extract surface and nadir-view temperatures for target.
- Select results for albedo and dust opacity based on observations

- Logarithmic interpolate at observed temperature to derive thermal inertia

- Time is not an issue. Can do entire TES or THEMIS model set* in an hour.
  - Mellon models took a week.

- * 48 times of day, 37 latitudes, [168+] 84 seasons,

  3 albedos, 3 opacities, 3 elevations, 10 inertias.

Output

- Default print file (krc.prt) lists all changes, then the full input list, then the layer table, which should usually be contemplated.
- Options to turn on many kinds of printout.
  - Beware: file can get huge.
- Binary output files: 7 kinds in two sets: controlled by K4OUT
- Fortran direct access. [Allows restart at any recorded season]
- -1: Used for major model runs. Outputs KRCCOM, which contains all the input parameters, then arrays of Surface kinetic temperature and Planetary Bolometric Temperature for each season.
- 0: LATCOM. Arrays of several variables versus latitude and depth
- +1: DAYCOM for the last latitude for each season. Arrays of variables versus time-step or Hour or convergence-day.

Bin5 Binary output arrays

- +51: Minimum and Maximum temperature for all layers, 5 latitudes, 40 seasons, 5 cases
  - Layers 29,30 contain Tp_min, Tp_max, L_sub_s, Julian Day
- +52: 24 hours, 6 items, 5:10 lats, 1+<=80 seasons, <=5 cases)
  - Items are: Tsurf, Tplan, Tatm, DownVis, DownIR, spare
  - First "season" contains: KRCCOM and 3 season variables
- +53: Combo at 1 lat, 2+80 seasons, 10 cases
  - Combo: Tsurf & Tplan @ 24 hours; Tmin & Tmax @ 30 layers,
  - Asol @ 24 hours. The first 2 "seasons" contain KRCCOM
- +54: 68:740 seasons, 3 items, 1+<= 5 lats, <=10 cases
  - 3 items are: heat flow, surface temperature, frost amount
  - Store KRCCOM in the first latitude

Model sets and Determination of Thermal Inertia

- Two large set of models have been pre-computed.
  - Both have: Two year run-up, 3 albedos, 3 opacities, 3 elevations, logrithmic inertia. Tsur and Tplan output at 24 Hour points:
- Mellon: Used for TES production.
  - 84 seasons, 39 latitudes, 10 Inertias (25:800)
- KRC: recent run, plan to extend to I>=2000
  - 84 seasons, 37 latitudes, 15 Inertias (25:800), 3 albedos, 3 pressures, climate odust and ice opacities, 9 slopes [K4OUT=-1]
- Interpolation: described in Mellon,Jakosky, Kieffer and Christensen (2000): Icarus, 148, on page 441.4a
  - Season: linear
  - Albedo, opacity, elevation: quadratic
  - Hour and Latitude: bilinear
- Yields a set of 10 temperatures. Finds set between Tmin and Tmax
  - Inertia: linear in logarithm, And dT/dI for final interval

Installation and Supporting documentation

KRC installed at ASU

Helplist.tex Guide to running KRC

/mars/u/hkieffer/cop/krcCorP2.pdf Corrected version of JGR article

HeatOft.pdf Temperature dependence of rock thermal properties

Cement.pdf Particulate thermal conduction

newKRC.ppt 2008 powerpoint with some more details

mkrc.pdf making thermal movies

Have a look at ~/phil/ls09_32_full_5_part_movie.mov

Expect all this to be in Team-access area.

Will become public upon publication of the KRC paper

Coding Philosophy

- Place the large-loop actions (seasons, latitude) in separate routines
- Communicate via commons
- All dimensions set in the main common: krccom
- Minimize operations in the inner-most loop
- Implicit none in all routines that use commons
- tday.f: top section sets up the layer and time system
- Called once per case

A few aspects of FORTRAN

One of the earliest languages (FORmula TRANslator) and still widely used for heavy-duty computing (large scientific models)

Language has evolved, but largely backward compatible.

1-based indexing

- Default typing based on first letter of name
- I,J,K,L,M,N: default-length (4-byte) integers
- A-H,O-Z: single-precision floating-ping (REAL)

However, KRC mostly uses IMPLICIT NONE (contained in krccom.inc), which requires that each variable be explicitly typed.

Subroutine values NOT remembered by default, but can be SAVED or placed in (named) COMMON block

EQUIVALENCE puts items in the *same place in memory*, <u>including all related to it</u>

Some bad habits (speedy treachery) in KRC

Pitiful excuse: 8 Mbyte took half a floor!

Overloading: use the same variable for different things at different times

Equivalence: can place different things in the same place in memory

Use of REAL vectors to hold strings

DO LOOP indices placed in COMMON.

Allows reporting just where program was at an error

Use of COMMON simply to ensure remembrance

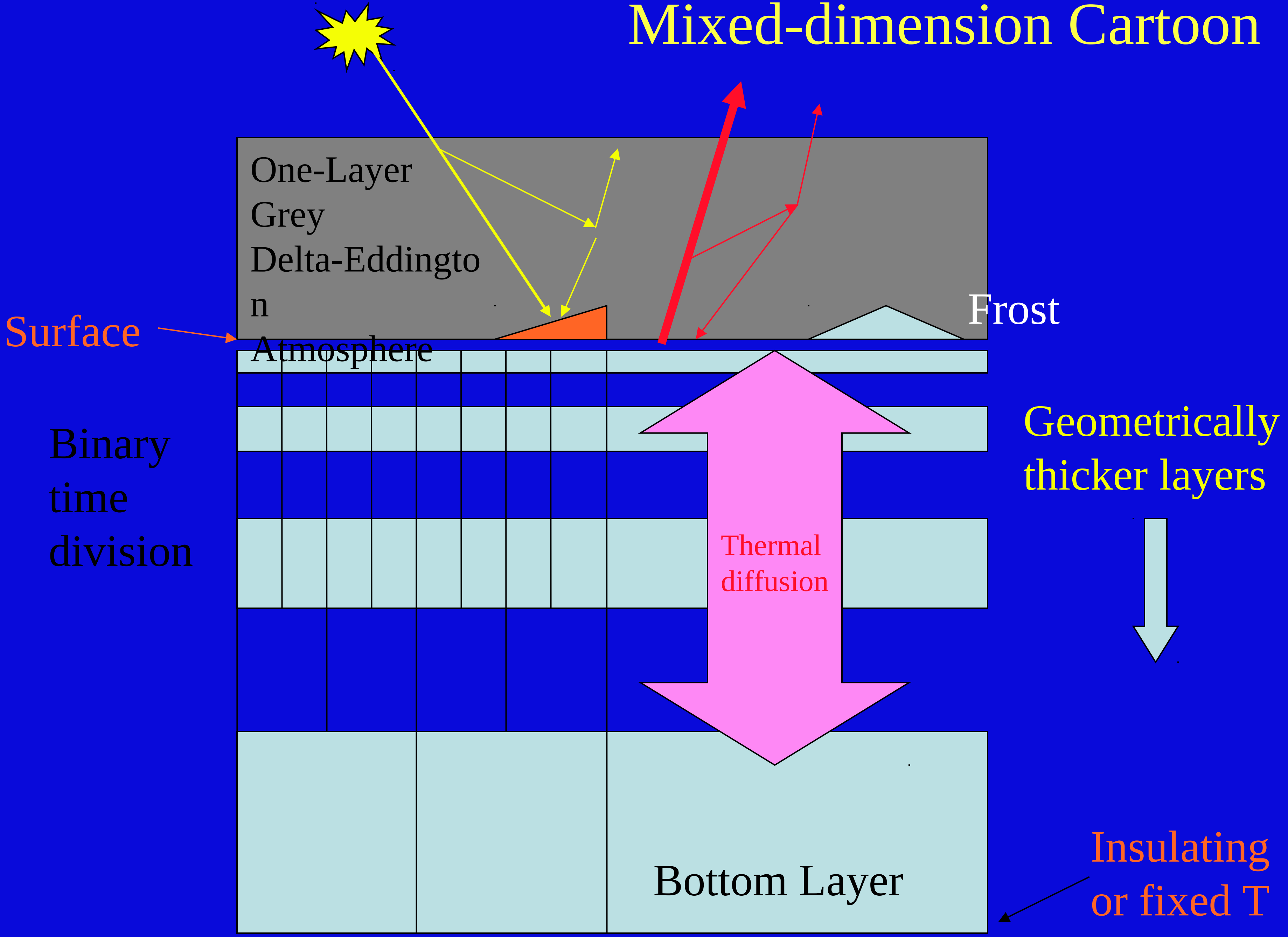
Use of subroutines to move things in memory.

E.g., r2r: (from,to,number(of 4-byte words)) N negative ⇨ from is a constant

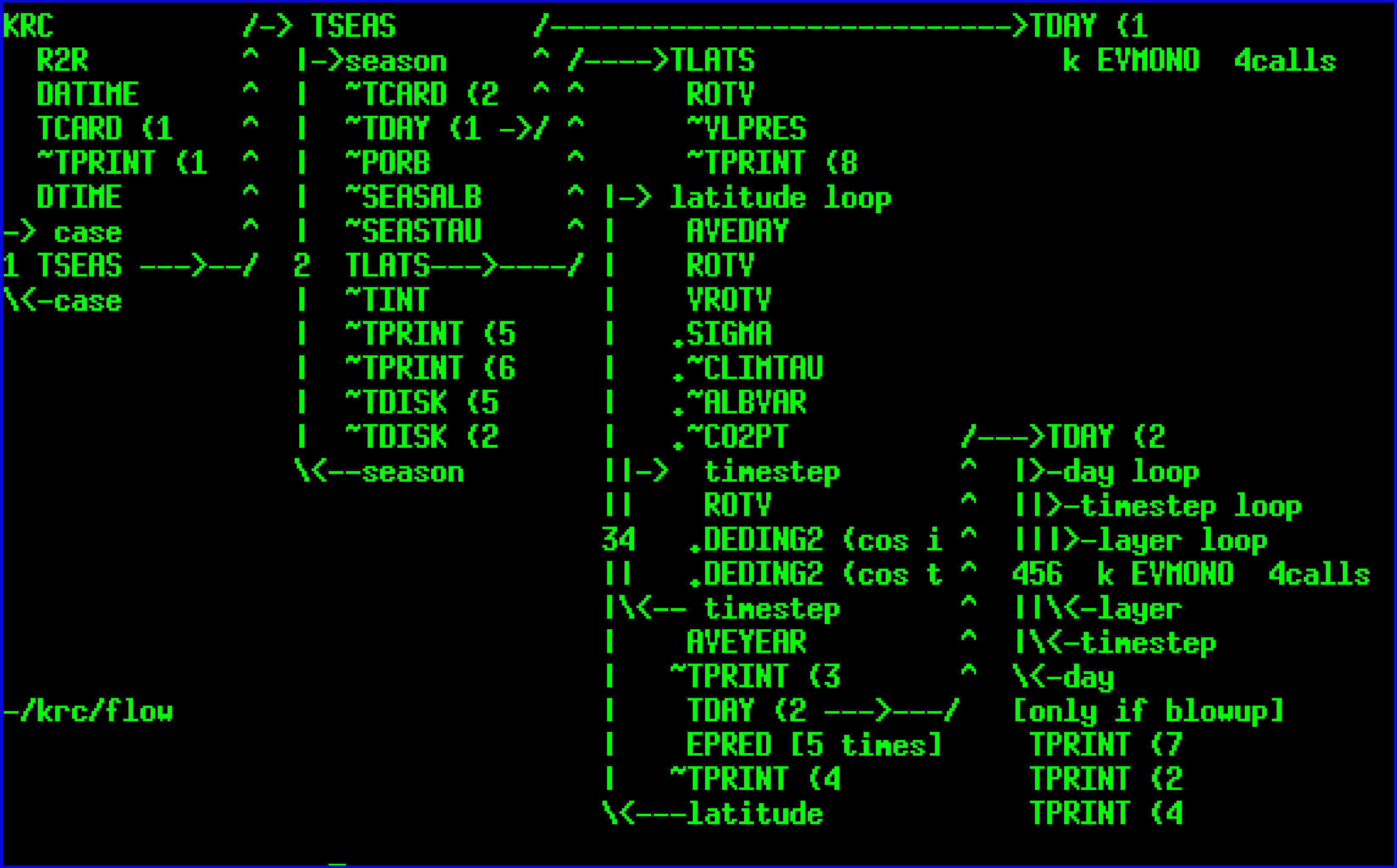
Does not care about actual types ! A seductive tool.

The C version checks for physical location, and runs backwards if needed.

Mixed-dimension Cartoon



Flow: Loops and Calls



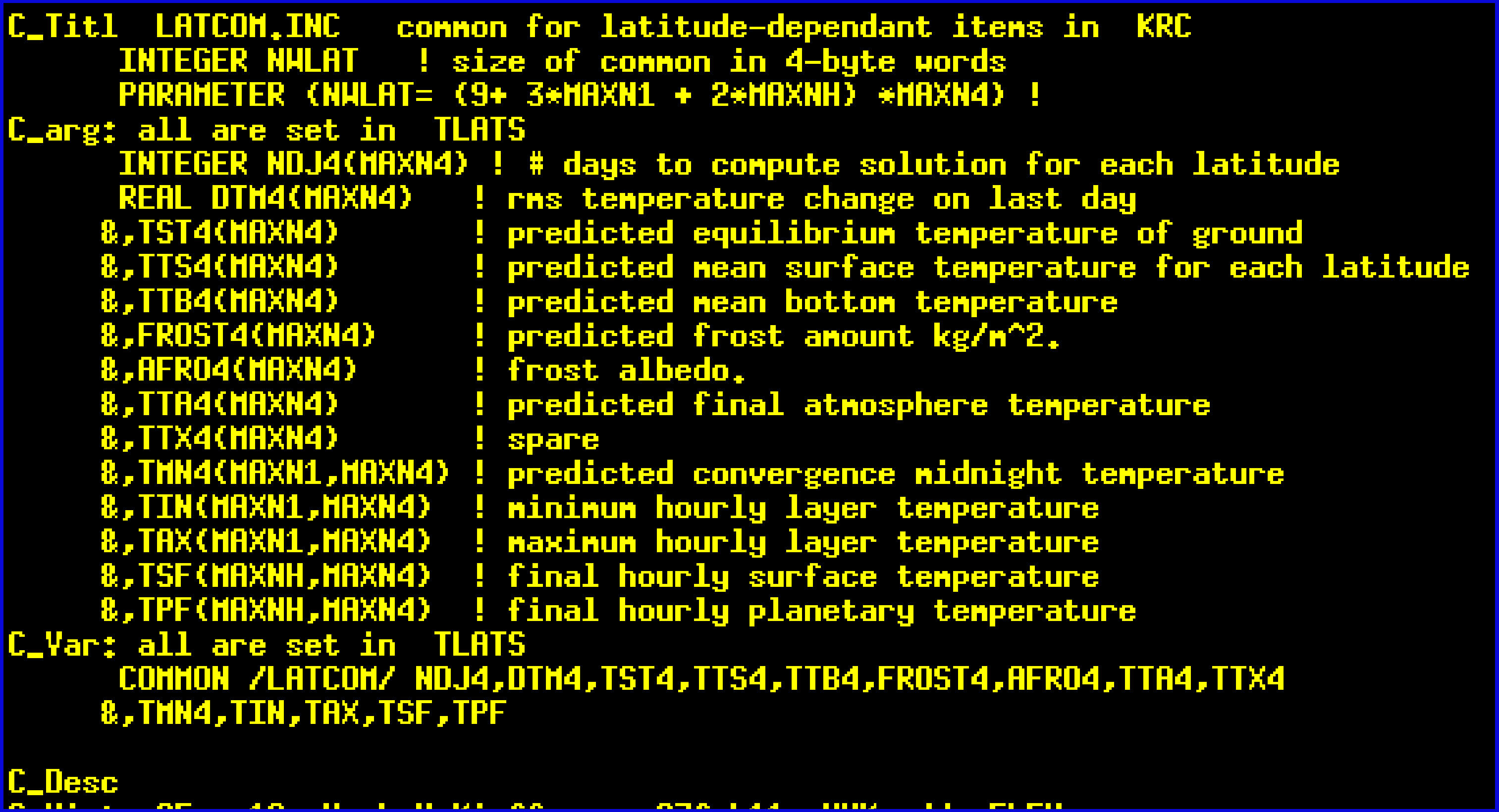
```
KRC           /-> TSEAS        /--------------------------->TDAY (1
  R2R         ^  |->season     ^ /---->TLATS                  k EVMONO  4calls
  DATIME      ^  |  ~TCARD (2  ^ ^      ROTV
  TCARD (1    ^  |  ~TDAY (1 ->/ ^      ~VLPRES
  ~TPRINT (1  ^  |  ~PORB        ^      ~TPRINT (8
  DTIME       ^  |  ~SEASALB     ^ |-> latitude loop
-> case       ^  |  ~SEASTAU     ^ |    AVEDAY
1 TSEAS --->--/  2  TLATS--->----/ |    ROTV
\<-case          |  ~TINT          |    VROTV
                 |  ~TPRINT (5     |   .SIGMA
                 |  ~TPRINT (6     |   .~CLIMTAU
                 |  ~TDISK (5      |   .~ALBVAR
                 |  ~TDISK (2      |   .~CO2PT          /--->TDAY (2
                 \<--season        ||->  timestep       ^  |>-day loop
                                   ||    ROTV           ^  ||>-timestep loop
                                   34   .DEDING2 (cos i ^  |||>-layer loop
                                   ||   .DEDING2 (cos t ^  456  k EVMONO  4calls
                                   |\<-- timestep       ^  ||\<-layer
                                   |    AVEYEAR         ^  |\<-timestep
                                   |   ~TPRINT (3       ^  \<-day
-/krc/flow                         |    TDAY (2 --->---/   [only if blowup]
                                   |    EPRED [5 times]     TPRINT (7
                                   |   ~TPRINT (4           TPRINT (2
                                   \<---latitude            TPRINT (4
```

~: optional

. : only if atmosphere

K: only if T-dependent

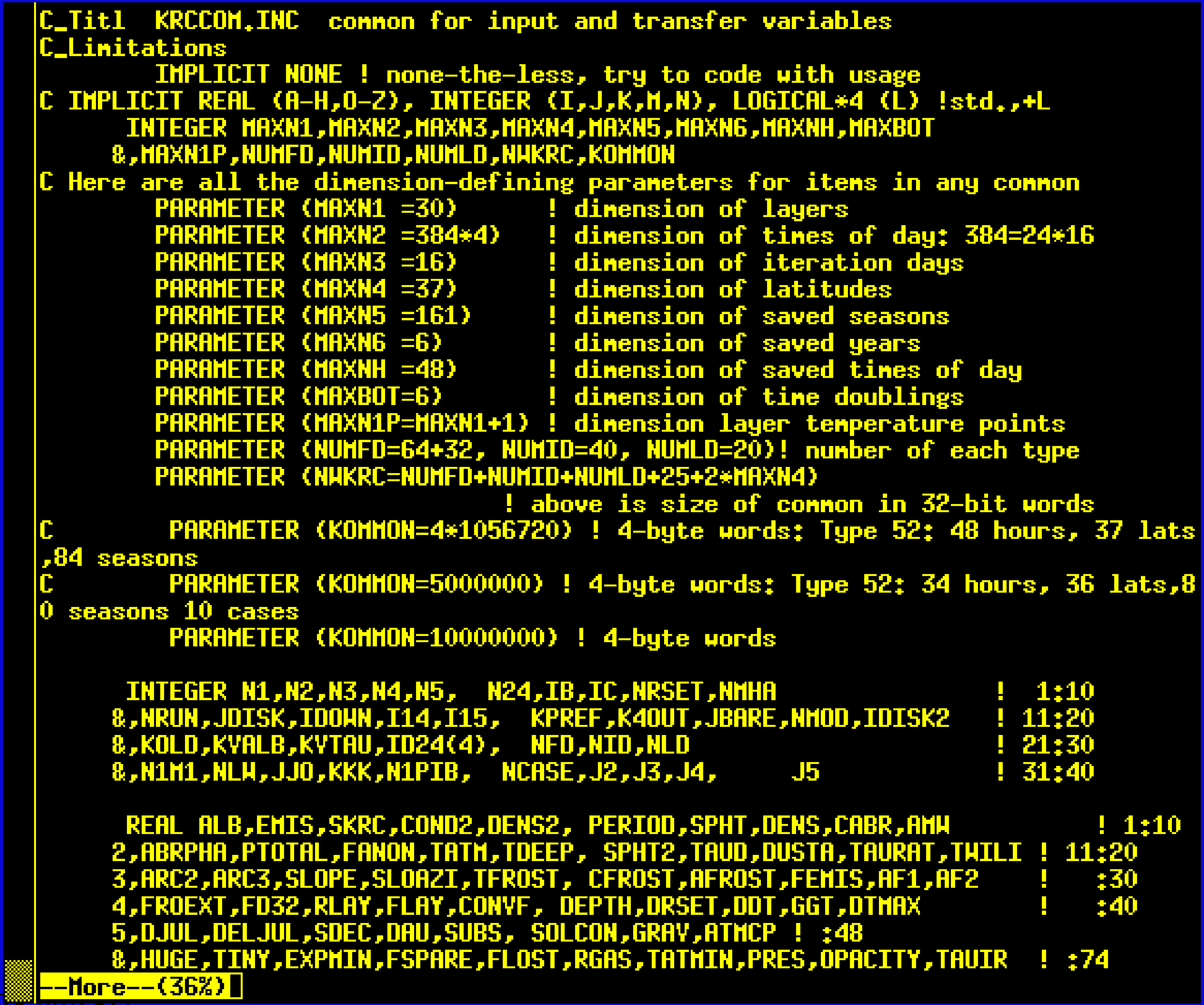
Latitude Common: latcom.inc



```
C_Titl  LATCOM.INC   common for latitude-dependant items in  KRC
      INTEGER NWLAT    ! size of common in 4-byte words
      PARAMETER (NWLAT= (9+ 3*MAXN1 + 2*MAXNH) *MAXN4) !
C_arg: all are set in  TLATS
      INTEGER NDJ4(MAXN4) ! # days to compute solution for each latitude
      REAL DTM4(MAXN4)   ! rms temperature change on last day
     &,TST4(MAXN4)       ! predicted equilibrium temperature of ground
     &,TTS4(MAXN4)       ! predicted mean surface temperature for each latitude
     &,TTB4(MAXN4)       ! predicted mean bottom temperature
     &,FROST4(MAXN4)     ! predicted frost amount kg/m^2.
     &,AFRO4(MAXN4)      ! frost albedo.
     &,TTA4(MAXN4)       ! predicted final atmosphere temperature
     &,TTX4(MAXN4)       ! spare
     &,TMN4(MAXN1,MAXN4) ! predicted convergence midnight temperature
     &,TIN(MAXN1,MAXN4)  ! minimum hourly layer temperature
     &,TAX(MAXN1,MAXN4)  ! maximum hourly layer temperature
     &,TSF(MAXNH,MAXN4)  ! final hourly surface temperature
     &,TPF(MAXNH,MAXN4)  ! final hourly planetary temperature
C_Var: all are set in  TLATS
      COMMON /LATCOM/ NDJ4,DTM4,TST4,TTS4,TTB4,FROST4,AFRO4,TTA4,TTX4
     &,TMN4,TIN,TAX,TSF,TPF

C_Desc
```

krccom.inc   top part



```
C_Titl  KRCCOM.INC  common for input and transfer variables
C_Limitations
        IMPLICIT NONE ! none-the-less, try to code with usage
C IMPLICIT REAL (A-H,O-Z), INTEGER (I,J,K,M,N), LOGICAL*4 (L) !std.,+L
      INTEGER MAXN1,MAXN2,MAXN3,MAXN4,MAXN5,MAXN6,MAXNH,MAXBOT
     &,MAXN1P,NUMFD,NUMID,NUMLD,NWKRC,KOMMON
C Here are all the dimension-defining parameters for items in any common
        PARAMETER (MAXN1 =30)       ! dimension of layers
        PARAMETER (MAXN2 =384*4)    ! dimension of times of day: 384=24*16
        PARAMETER (MAXN3 =16)       ! dimension of iteration days
        PARAMETER (MAXN4 =37)       ! dimension of latitudes
        PARAMETER (MAXN5 =161)      ! dimension of saved seasons
        PARAMETER (MAXN6 =6)        ! dimension of saved years
        PARAMETER (MAXNH =48)       ! dimension of saved times of day
        PARAMETER (MAXBOT=6)        ! dimension of time doublings
        PARAMETER (MAXN1P=MAXN1+1) ! dimension layer temperature points
        PARAMETER (NUMFD=64+32, NUMID=40, NUMLD=20)! number of each type
        PARAMETER (NWKRC=NUMFD+NUMID+NUMLD+25+2*MAXN4)
                                ! above is size of common in 32-bit words
C        PARAMETER (KOMMON=4*1056720) ! 4-byte words: Type 52: 48 hours, 37 lats
,84 seasons
C        PARAMETER (KOMMON=5000000) ! 4-byte words: Type 52: 34 hours, 36 lats,8
0 seasons 10 cases
         PARAMETER (KOMMON=10000000) ! 4-byte words

      INTEGER N1,N2,N3,N4,N5,  N24,IB,IC,NRSET,NMHA                     !  1:10
     &,NRUN,JDISK,IDOWN,I14,I15,  KPREF,K4OUT,JBARE,NMOD,IDISK2   ! 11:20
     &,KOLD,KVALB,KVTAU,ID24(4),  NFD,NID,NLD                      ! 21:30
     &,N1M1,NLW,JJO,KKK,N1PIB,  NCASE,J2,J3,J4,     J5             ! 31:40

      REAL ALB,EMIS,SKRC,COND2,DENS2, PERIOD,SPHT,DENS,CABR,AMW          ! 1:10
     2,ABRPHA,PTOTAL,FANON,TATM,TDEEP, SPHT2,TAUD,DUSTA,TAURAT,TWILI ! 11:20
     3,ARC2,ARC3,SLOPE,SLOAZI,TFROST, CFROST,AFROST,FEMIS,AF1,AF2    !   :30
     4,FROEXT,FD32,RLAY,FLAY,CONVF, DEPTH,DRSET,DDT,GGT,DTMAX        !   :40
     5,DJUL,DELJUL,SDEC,DAU,SUBS, SOLCON,GRAV,ATMCP ! :48
     &,HUGE,TINY,EXPMIN,FSPARE,FLOST,RGAS,TATMIN,PRES,OPACITY,TAUIR  ! :74
--More--(36%)
```

krccom.inc Part 1

```
C Here are all the dimension-defining parameters for items in any common
        PARAMETER (MAXN1 =30)     ! dimension of layers
        PARAMETER (MAXN2 =384*4)   ! dimension of times of day: 384=24*16
        PARAMETER (MAXN3 =16)     ! dimension of iteration days
        PARAMETER (MAXN4 =37)     ! dimension of latitudes
        PARAMETER (MAXN5 =161)            ! dimension of saved seasons
        PARAMETER (MAXN6 =6)      ! dimension of saved years
        PARAMETER (MAXNH =48)     ! dimension of saved times of day
        PARAMETER (MAXBOT=6)      ! dimension of time doublings
        PARAMETER (MAXN1P=MAXN1+1) ! dimension layer temperature points
        PARAMETER (NUMFD=64+32, NUMID=40, NUMLD=20)! number of each type
        PARAMETER (NWKRC=NUMFD+NUMID+NUMLD+25+2*MAXN4)
                              ! above is size of common in 32-bit words
C       PARAMETER (KOMMON=4*1056720) ! 4-byte words: Type 52: 48 hours, 37 lats,84 seasons
C       PARAMETER (KOMMON=5000000) ! 4-byte words: Type 52: 34 hours, 36 lats,80 seasons 10 cases

          PARAMETER (KOMMON=10000000) ! 4-byte words


      INTEGER N1,N2,N3,N4,N5,  N24,IB,IC,NRSET,NMHA              !  1:10
     &,NRUN,JDISK,IDOWN,I14,I15,  KPREF,K4OUT,JBARE,NMOD,IDISK2   ! 11:20
     &,KOLD,KVALB,KVTAU,ID24(4),  NFD,NID,NLD                   ! 21:30
     &,N1M1,NLW,JJO,KKK,N1PIB,  NCASE,J2,J3,J4,    J5             ! 31:40
```

Inclusion of commons
Copy from re-arranged Makefile

```
krc.o:   krc.f krccom.inc latcom.inc daycom.inc units.inc filcom.inc
tseas.o: tseas.f krccom.inc latcom.inc hatcom.inc units.inc
tlats.o: tlats.f krccom.inc latcom.inc daycom.inc hatcom.inc units.inc
mlats.o: mlats.f krccom.inc latcom.inc daycom.inc hatcom.inc units.inc
tday.o:   tday.f krccom.inc daycom.inc hatcom.inc units.inc
tcard.o: tcard.f krccom.inc latcom.inc daycom.inc units.inc filcom.inc
tprint.o: tprint.f krccom.inc latcom.inc daycom.inc units.inc filcom.inc
tdisk.o: tdisk.f krccom.inc latcom.inc daycom.inc hatcom.inc units.inc filcom.inc
tint.o: tint.f krccom.inc
seasalb.o: seasalb.f units.inc filcom.inc
seastau.o: seastau.f units.inc filcom.inc
climtau.o: climtau.f  units.inc filcom.inc
porb0.o: porb0.f units.inc porbcm.inc
albvar.o: albvar.f krccom.inc
alsubs.o: alsubs.f krccom.inc
```

krccom.inc Lower part

```
      COMMON /KRCCOM/
     1 ALB,EMIS,SKRC,COND2,DENS2, PERIOD,SPHT,DENS,CABR,AMW        ! 1:10
     2,ABRPHA,PTOTAL,FANON,TATM,TDEEP, SPHT2,TAUD,DUSTA,TAURAT,TWILI ! 11:20
     3,ARC2,ARC3,SLOPE,SLOAZI,TFROST, CFROST,AFROST,FEMIS,AF1,AF2   !   :30
     4,FROEXT,FD32,RLAY,FLAY,CONVF, DEPTH,DRSET,DDT,GGT,DTMAX       !   :40
Cset                                   *day1
     5,DJUL,DELJUL,SDEC,DAU,SUBS, SOLCON,GRAV,ATMCP    !   :48
Cset                                        v total of 56 input
     5,CCKU,CCKL,CCPU,CCPL,HUGE,TINY         !  :66
     &,EXPMIN,FSPARE,FLOST,RGAS,TATMIN,PRES,OPACITY,TAUIR,TAUEFF,TATMJ  ! :76
Cset   *seas      ----seas-------
     6,SKYFAC,TFNOW,AFNOW,PZREF,SUMF, TEQUIL,TBLOW, HOURO,SCALEH,BETA !  :86
Cset   -----------lats--------- tint ---lats-------     ---lats----
     6,DJU5,DAM,EFROST,DLAT,COND,  DIFFU,SCALE,PIVAL,SIGSB,RADC      ! :96
Cset   seas lat day2   lats -------day1------- --main------
     7,N1,N2,N3,N4,N5,  N24,IB,IC,NRSET,NMHA                  !  1:10
     8,NRUN,JDISK,IDOWN,I14,I15,  KPREF,K4OUT,JBARE,NMOD,IDISK2   ! 11:20
     9,KOLD,KVALB,KVTAU,ID24,  NFD,NID,NLD                    ! 21:30
Cset          ----card---
     A,N1M1,NLW,JJO,KKK,N1PIB,  NCASE,J2,J3,J4,    J5            ! 31:40
Cset   ---day1- lat ----day1-    main -day2- lats  seas
     B,LP1,LP2,LP3,LP4,LP5,    LP6,LPGLOB,LVFA,LVFT,LKOFT        !  1:10
     C,LPORB,LKEY,LSC,LNOTIF,LOCAL,   LD16,LD17,LD18,LD19,LONE       ! 11:20
     D,TITLE,DAYTIM,ALAT,ELEV   !
Cset   tcard tprint tcard tcard
C
      EQUIVALENCE (FD(1),ALB), (ID(1),N1), (LD(1),LP1)
```

What makes it fast

- Geometrically increasing layer thickness with depth
- Progressive time-step doubling as layer thickness allows for numerical stability
- Jump perturbations to equalize average temperature with depth in the first season
- Asymptotic predictor after convergence to the end of a season
- Pre-calculate frequently-used terms (Modern optimizer would do this)

Major Limitations

- Can not do really thin surface layers

Some Details

TBLOW: stops if this is exceeded by surface kinetic temperture

Twice the temperature of black plate facing the Sun

TBLOW=2.*√√[(Solar constant/distance^2)/(Emissivity*σ)]

Heliocentric distance, Solar declination, Ls

PORB returns, for a modified Julian Date (JD-2 440 000),

DAU=heliocentric distance in AU(distance for which Solar Constant is defined)

PEA,PEB=latitude,longitude(radians) of planet in heliocentric ecliptic coord.

HFA,HFB=latitude,longitude(radians) of Sun in planetocentric fixed coordinates

Packing of bin5 files

All done and remembered in TDISK (tdisk.f)

When called with a 1: sets up 10-element JJJ with sizes that will go into the bin5 header

1) the number of dimensions to the array

2:N+1) size of those dimensions

Type 52: (hours,7,latitudes,x+seasons,cases)

First x seasons contain, for each case:

- Float of 4 integers that define sixes
  - Total size of krccom transfered
  - 1-based index of the dimension with extra values
  - Number of those extra dimensions
  - spare
- Floating point of krccom
- Array(nseas,5) DJU5,SUBS,PZREF,TAUD,SUMF

For true seasons, the 7 contain:

- 1: TSF, surface kinetic temperature
- 2: TPF, planetary bolometric temperature
- 3: TAF. Atmosphere kinitec temperature
- 4: DOWNVIS:
- 5: DOWNIR
- 6: packed: float(NDJ4)+ DTM4 + TTA4+ Tmin(Nlay-) || Omitting the virtual
- 7: packed: FROST4+ AFRO4+ HEATMM+ Tmax(Nlay-) || first layer

Reading packed bin5 files

```
readk52.pro, finame,ttt,uuu,vvv,itemt,itemu,itemv, ddd,ggg,itemd,itemg ,t51=t51

;finame in.  String of file name
; ttt   out.    Fltarr(hour,item,latitude,season,case) Item labels are in itemt
;                    0= surface kinetic temperature
;                    1= Top-of-atmosphere bolometric temperature
;              t52     2= one-layer atmosphere kinetic temperature
;              t52     3= Down-welling solar radiance
;              t52     4= Down-welling thermal radiance
; uuu   out.    Fltarr(nlat,item,case) Item labels are in itemu
;                    0= Latitude in degrees
;                    1= elevation in Km.
; vvv   out.    Fltarr(season,item,case) Item labels are in itemv
;                    0= Model season julian date - 2,440,000
;                    1= L-sub-S computed in KRC
;                    2= Global mean pressure: PZREF
; itemt,u,v  out.   Strarr ID's for the items in ttt, uuu, and vvv
; Following 4 outputs not valid for Type 51
; ddd   out.    Fltarr(layer,item,latitude,season,case) Item labels are in itemd
;                    Item:  0=Tmin    1=Tmax
; ggg   out.    Fltarr(item,latitude,season,case) Item labels are in itemg
;               Items: 'NDJ4','DTM4','TTA4','FROST4','AFRO4','HEATMM'
; itemd,g out.  Strarr ID's for the items in ddd, and ggg
; t51   in_     Flag. If set, presumes input file is type 51
; func. out.    Fltarr of L-sub-S corresponding to Jul.Day for the first case.
;               If an error, returns negative integer
;        -1: -4 are from READKRCCOM, -5 = failure here
```

Readkrc52: lower calls

bin5.pro: BIN5,'R',finame,head,aaa,/verb

reads the bin5 packed array

readkrccom.pro:

;Use: Call initially, q=READKRCCOM('filename',hold) where hold may be undefined

; To get a case kcom=READKRCCOM(Icase,hold) where hold is unchanged

; When done with file: READKRCCOM(-1,hold) or free_lun,hold[0]

;_Calls DEFINEKRC

Hold is 4 words: [lun, size-of-case, # cases, nwkrc]

definekrc.pro: Define structures in IDL that correspond for Fortran commons

Basically a translation of krccom.inc, latcom, daycom or filcom into IDL, with default or fake values. Therefor MUST AGREE with the krccom used to write the file.

PORB: Planetary ORBit calculator

```
PORBMN  Main program. Includes 'porbcm.inc'
  DATIME   Returns current date and time
 may call the following in any order. All INCLUDE 'porbcm.inc'
  PORB1    Read orbital elements, compute matrices
    PORBEL    Read any of 4 orbital element files, compute basic constants
      YMD2JD    Convert year, month, day to Julian date offset from 2,440,000
    OBLIQ     Compute Planets poles in ecliptic coord and nodes
    OBLIP     Compute obliquity of a planet
    ROTDIA 2x
    ROTAX  10x
  PORBIO   Read/write Common to file as text or binary
  EPHEMR   Print ephemeris == geometry versus time
    PORB     Computes planetary angles and location for specific time
      ORBIT    Compute location of body in its orbital plane
      ROTVEC    Apply rotation matrix to rotate a vector
    CALDATE
    SPCREV
    ANG360
  PORBQQ   Test computation of matrices
    ROTDIA 2x
  ROTAX  4x
  MPRINT 3x
  MPROD3 2x
```

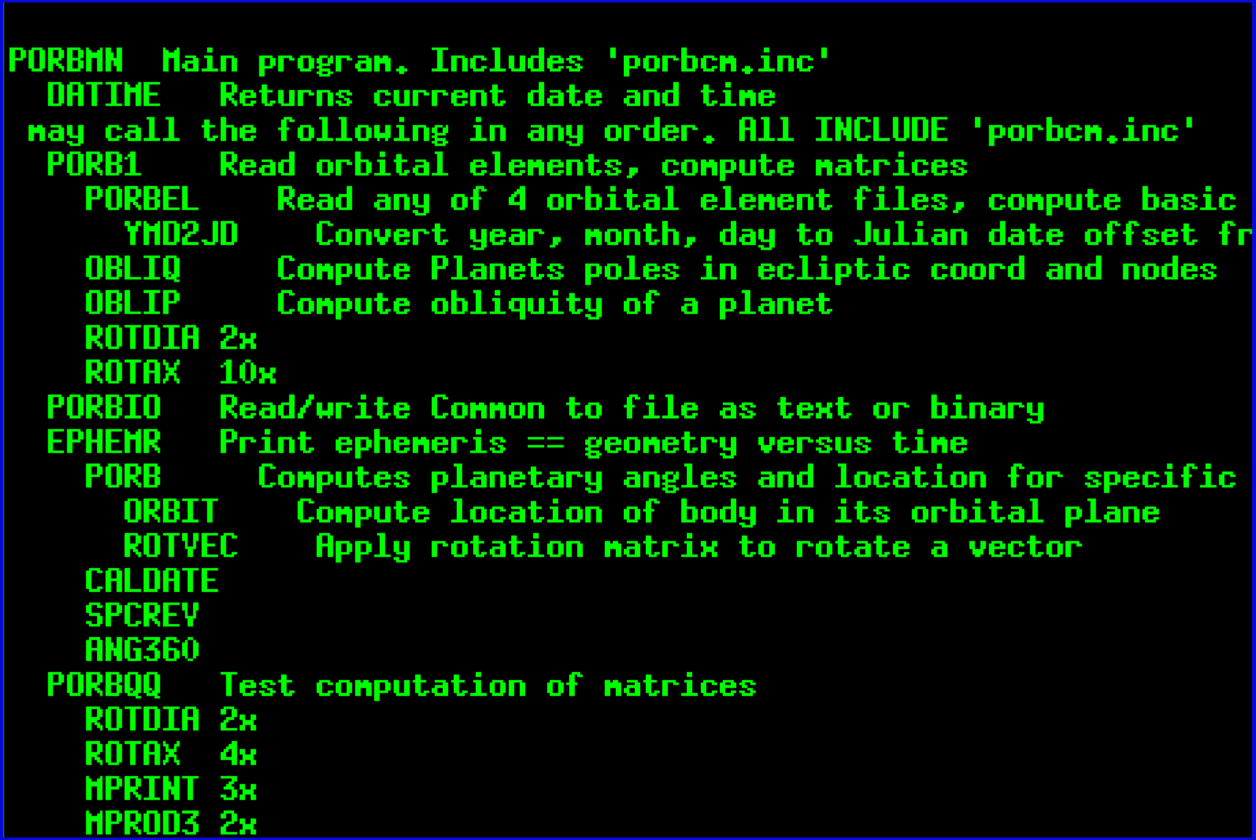
PORB: Planetary ORBit calculator

Runs as stand-alone program   porbmn.f

Subroutine PORB used by KRC

Key input are the [four] elements formatted-text files

Users guide: PORBguide.txt



```
PORBMN  Main program. Includes 'porbcm.inc'
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    OBLIP     Compute obliquity of a planet
    ROTDIA 2x
    ROTAX  10x
  PORBIO    Read/write Common to file as text or binary
  EPHEMR    Print ephemeris == geometry versus time
    PORB     Computes planetary angles and location for specific
      ORBIT    Compute location of body in its orbital plane
      ROTVEC    Apply rotation matrix to rotate a vector
    CALDATE
    SPCREV
    ANG360
  PORBQQ    Test computation of matrices
    ROTDIA 2x
    ROTAX  4x
    MPRINT 3x
    MPROD3 2x
```

Debug print options

If first input line has third non-zero integer, then will read a an extra 2nd line of six integers: IDB1,IDB2,IDB3,IDB4,IDB5,IDB6

These control optional WRITE statements as listed in helplist section on DEBUG OPTIONS

Restart for prior run. Powerful & delicate

First input line: KOLD & KEEP [& KDB]

KOLD: record of prior run to start with. Will fill KRCCOM and Latitudes and elevations from prior run, and use the kinetic tempertures of the layers at the end of the specified season.

Must not change the layering scheme.

KEEP: Flag, 0=do not write to this file. Else, leaves the file open,

And will start writing based on JDISK

Not sure this still works:

If an error occurs:

Compare your input file to the master.

- Unix: use diff

Check the helplist definition for each item that was modified

If can not get it to run properly ---

Send three files to the mentor:

- Input file
- What appeared on the screen
- Print file

Liens

binf5.F Detecting hardware architecture. Near line 122.

Currently does not detect, so swap might no happen.

Bastion : uname -p = i686   -i = i386

Hulk2: x86_64 for both

Add version: to print, monitor and bin5.   Here are all the steps:

transfer through filcom.inc: CHARACTER*12 VERDAT

krc.f   VERDAT='KRC2013jan27'

```
         WRITE (IOPM,*)'This is:',VERDAT
```

tdisk.f HEADER --> HEADTX (header appears in many commens)

```
        CHARACTER*3 CSTAT ! File status and string version of KODE
           CHARACTER*25 HEADTX
           write(cstat,*)kode  ! converts file type to string
           HEADTX=VERDAT//' tdisk Type'//CSTAT   ! 12+10+3
```

tprint.f at 800, replace ' RUN-CASE' with VERDAT as A12

Liens: 2

Decide how to handle “master” version of code during transition

Automate processing of a new Distribution

Helplist:

- Rename .tex to .txt
- Make html version with index
- Make pdf version with index

Remove the alternate input options (not used for a long time)

?? Remove the debug options

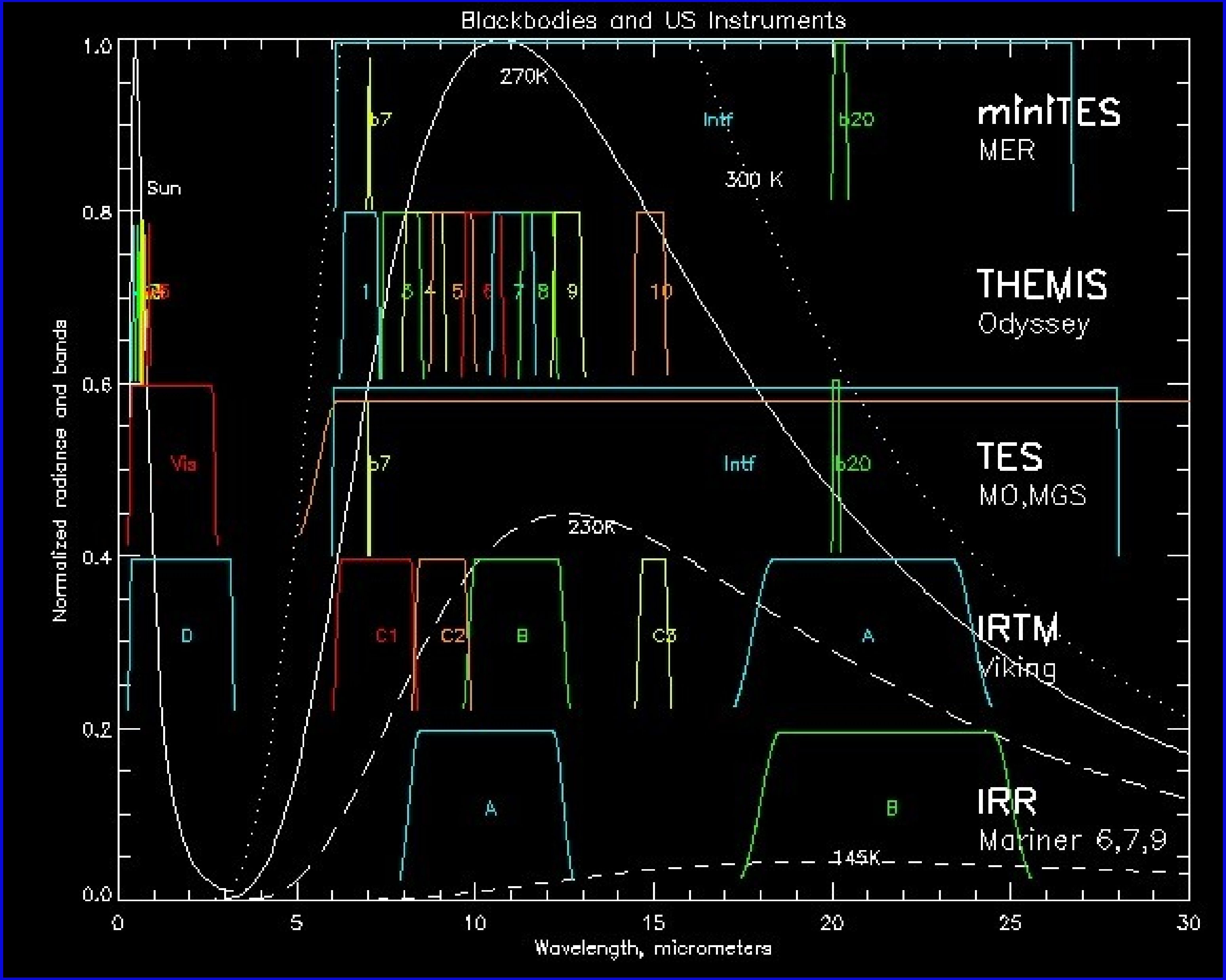
Resolve the extra-word issue between FORTRAN and IDL

Make a re-ordered entry form for input: output the current input file

- Real time limit checks (some are linked)
- Put expert-only items last
- May be a challenge to retain flexability

Extras

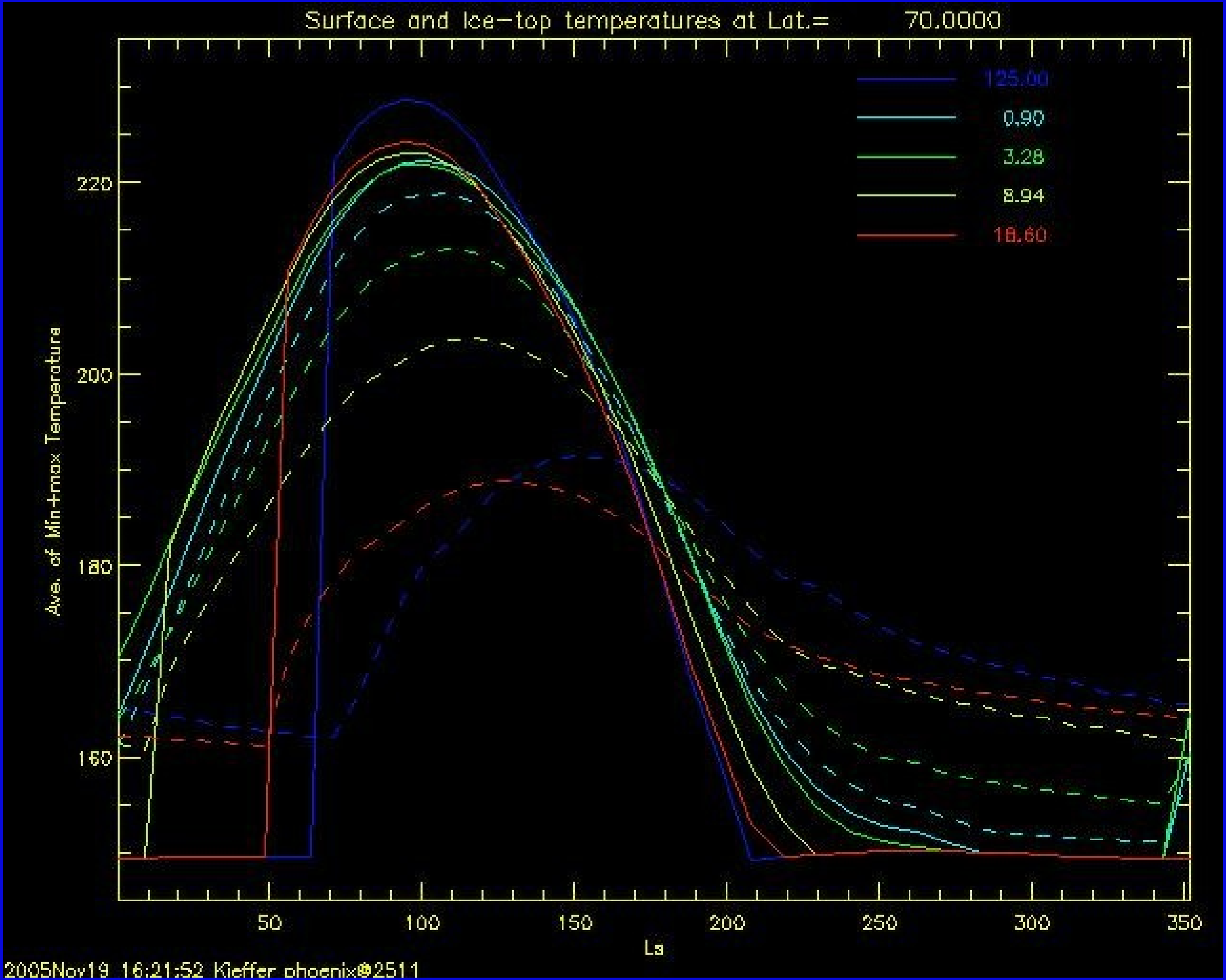
Evolution of Mars’ thermal instruments



Phil’s

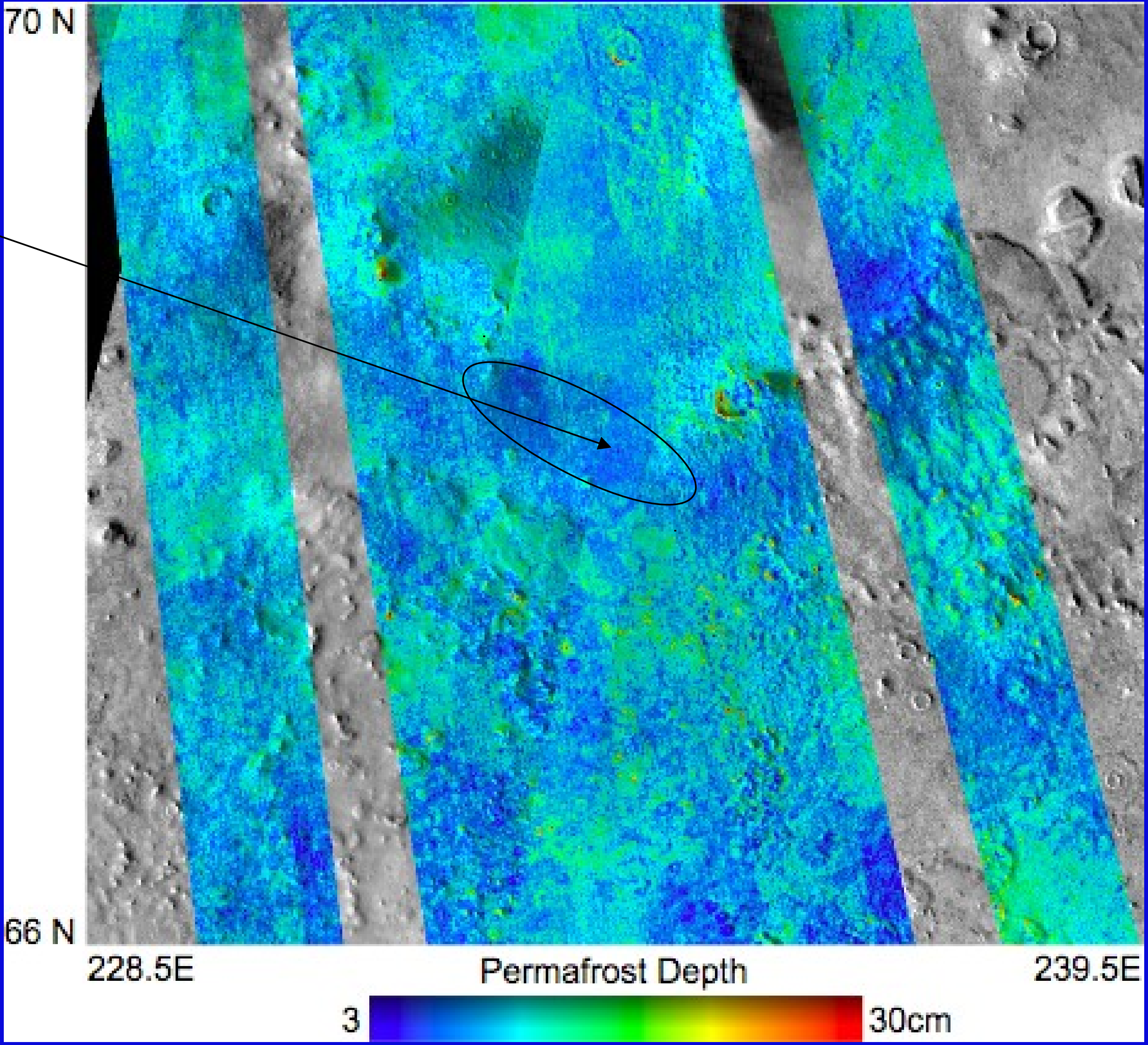
All Uncooled !!

KRC: Effect of depth to ice



Bandfield et al. THEMIS mapping of landing region

Phoenix
Landing
site



Regional:
TES:
I=258,
Z=4.5cm

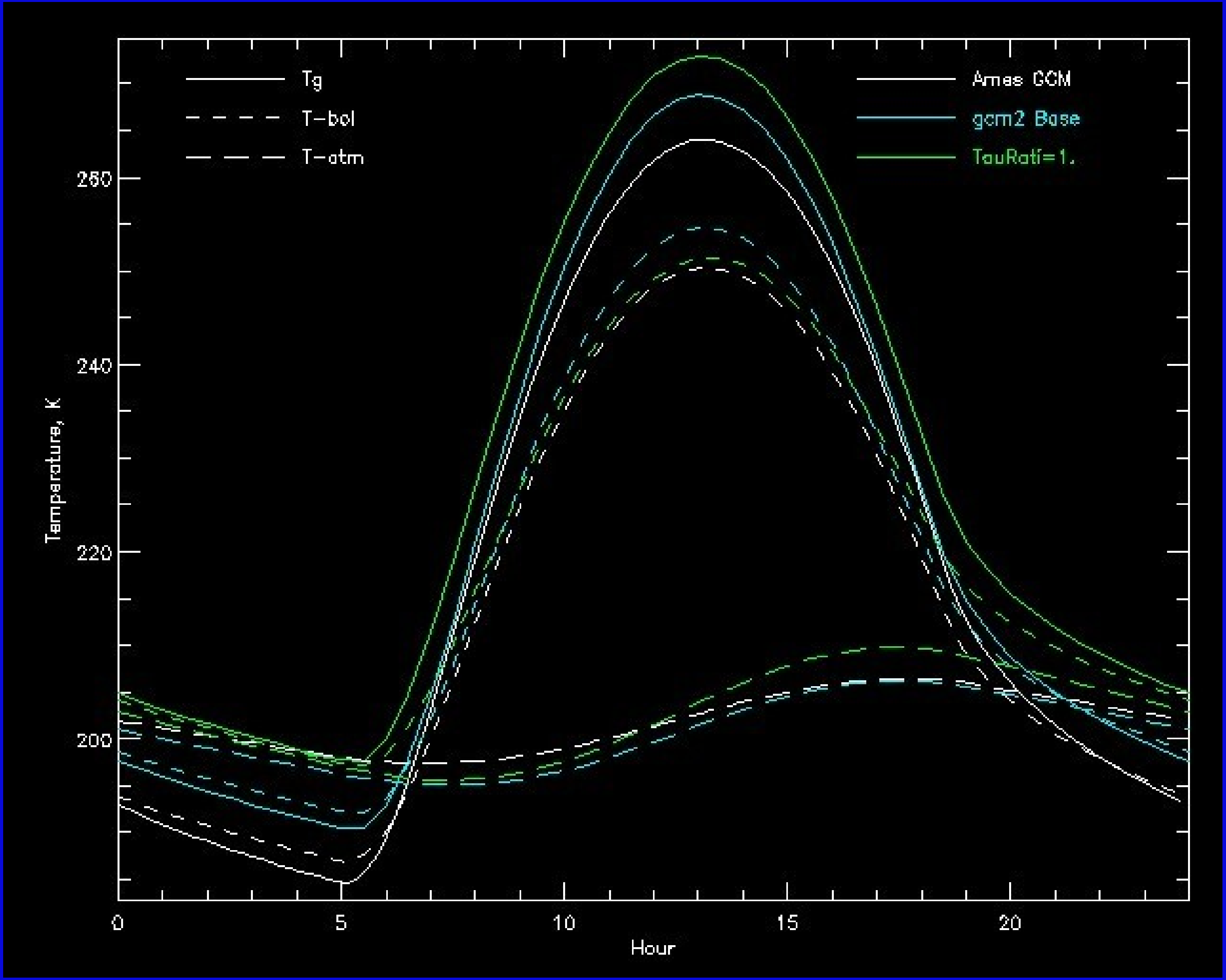
THEMIS:
I=283
Z=6.2cm

Mix of Rocks and fines is common

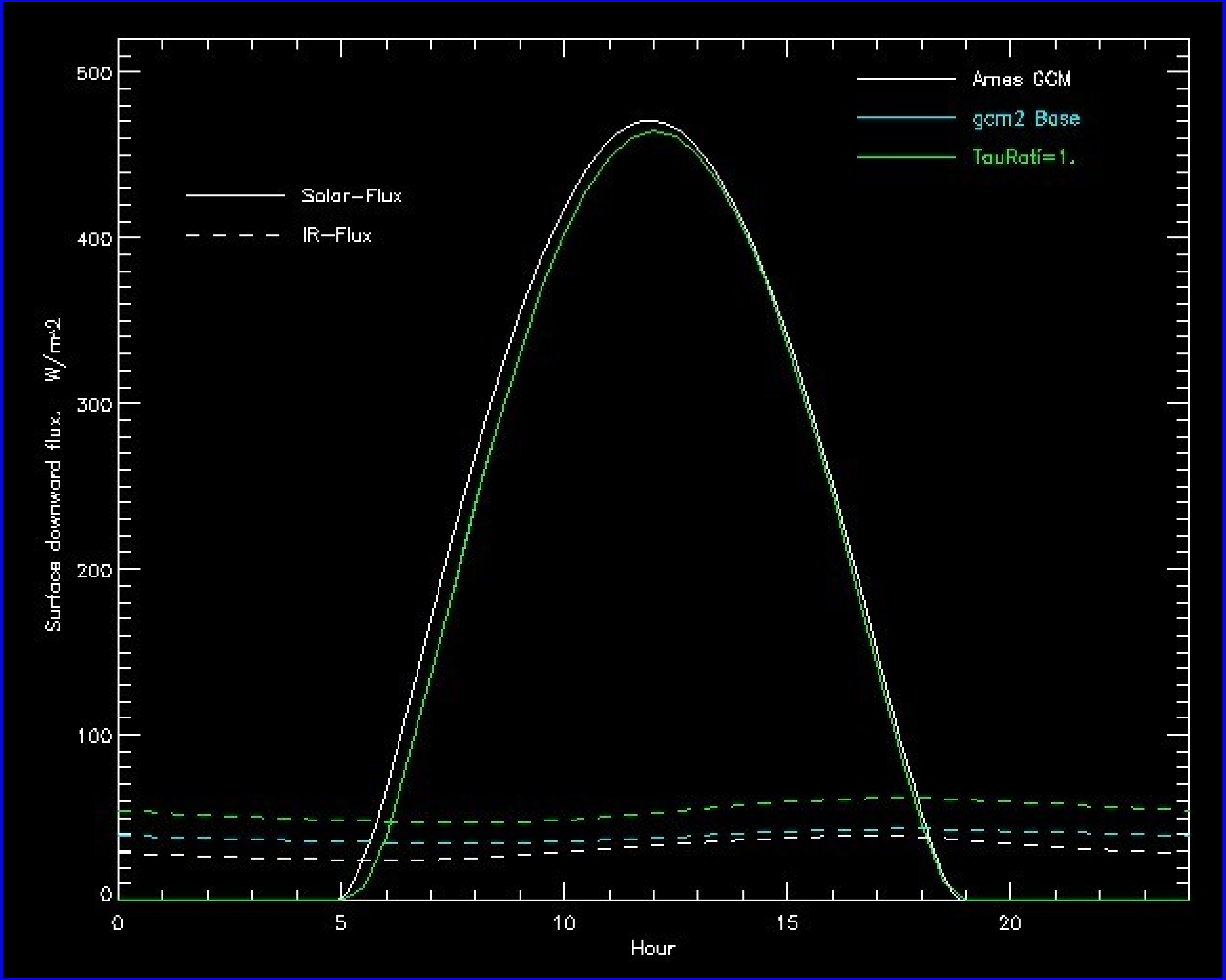
- Rocks dominate at night
  - Anything larger than ~10 cm
- Fine particles dominate in day
- Using day and night observations allow determination of **rock fraction** and drift particle size.
- Good predictions for landing sites
- With spectral information, need to weight radiances, not temperatures
- KRC is for one vertical situation at a time.
- Linear addition of models represent scenes of mixed rocks and fines
- Mixed scenes do not look like blackbodies; brightness temperature increases toward shorter wavelengths
- Day+night observations [or spectral analysis] allow separation of rocks from fines.

- Rock fraction is a major criterion for landing sites.

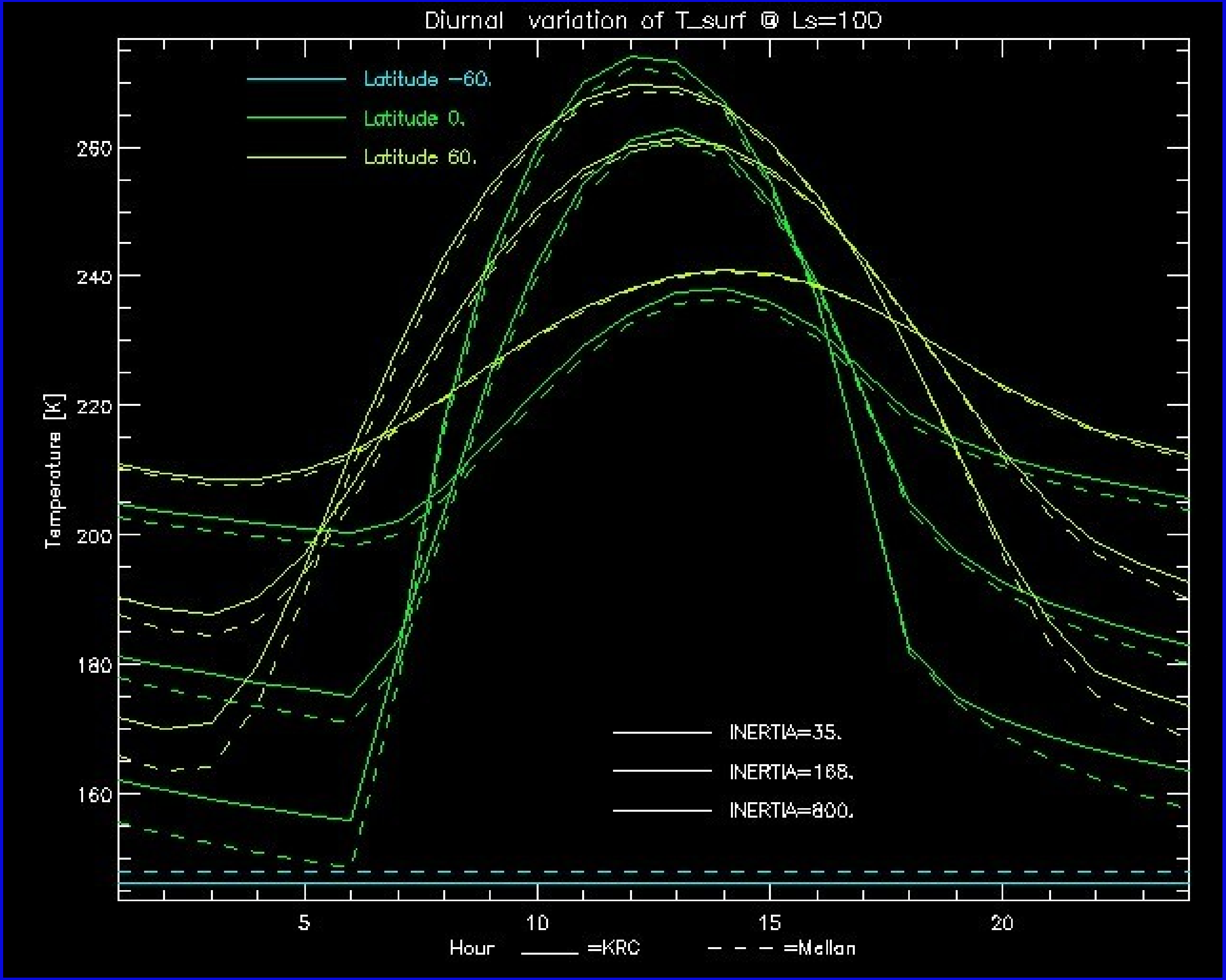
Comparison to Ames GCM model: temperatures



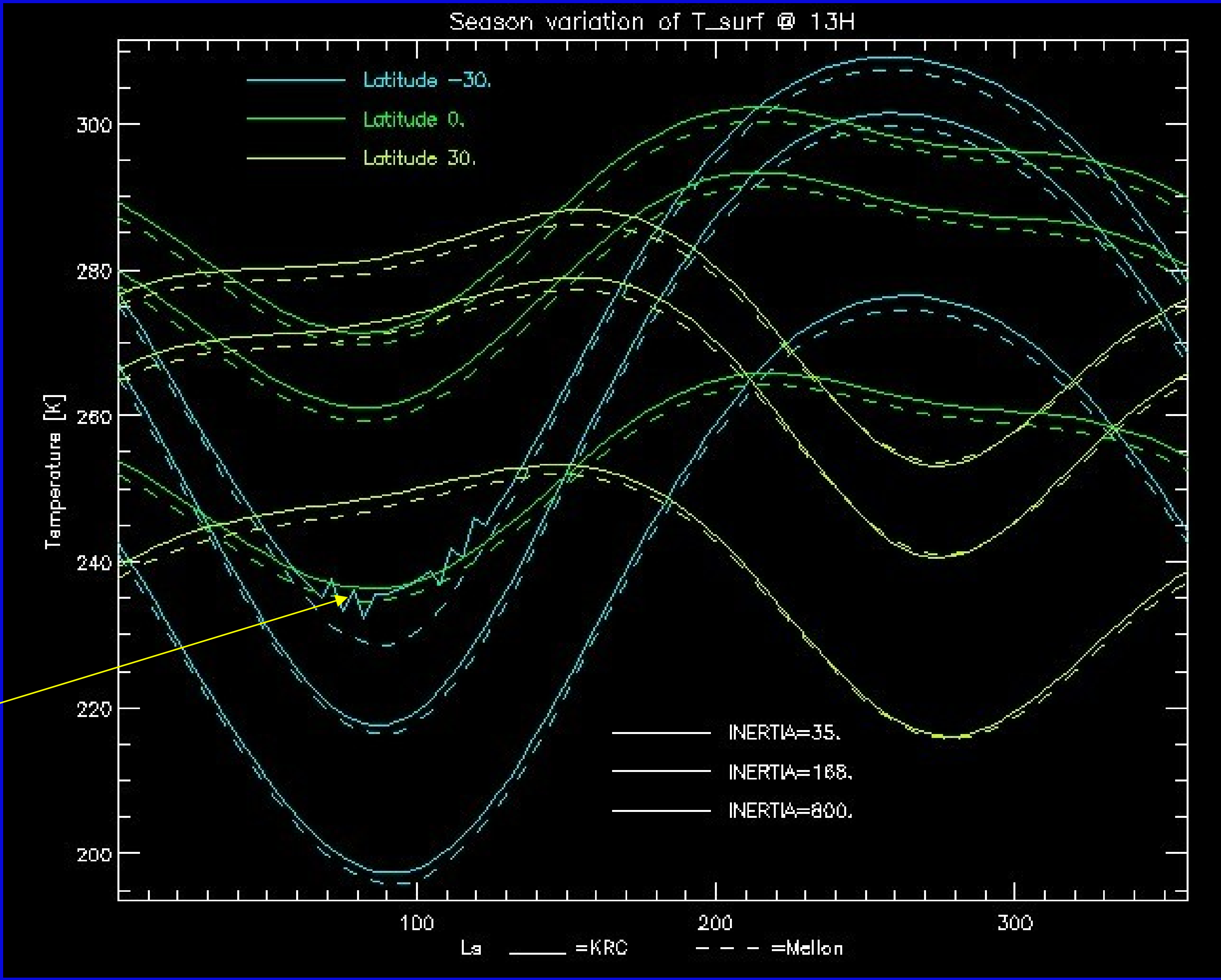
Comparison to Ames GCM model: downward flux



Comparison to Mellon Models (TES default): diurnal



Comparison to Mellon Models: seasonal



Night frost
30S I=35

Uncertainty of Thermal Inertia

- Deal with the uncertainty of measured temperature, as well as all of the parameters that go into the model.
- For simplicity, assume the “errors” are uncorrelated
- $U_I = \mathrm{RSS}\,[\, UT_b,\ UA\cdot \partial T_m/\partial A,\ U\tau \cdot \partial T_m/\partial \tau,\ U{\Downarrow} \cdot \partial T_m/\partial {\Downarrow},\ \ldots]\ /\ (\partial T_m/\partial I)$ at proper I

U = uncertainty   A=Albedo   τ =Opacity   ⇓=slope and azimuth

All the partial derivatives are available from a thermal model!

Run models with each U parameter individually perturbed

Or, subtract pairs of models in the large sets.

You have to assess the magnitude of the input Uncertainties