In order to discuss the correctness of this model, it is important to know what each of the variables stands for. The variables that can be changed are a, b, c, aice, tcrit, aland(). In this model , a stands for the longwave radiation lost to space that doesn't depend on the temperature, b is the coefficient of temperature in the equation for longwave radiation lost to space. The variable c is the coefficient of heat transport; it is more commonly known as k. Aice is the albedo of ice. The temperature at which the surface becomes ice covered is tcrit. Finally aland() is an array that gives the albedo of the ground in each latitudinal section.

With initial conditions and all the solar constant, the output is ...

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                               R E S U L T S
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
          Zone                 Temperature           Albedo
       =============          ===========            ======
             80-90              -13.5                  0.62
             70-80              -12.9                  0.62
             60-70               -4.8                  0.45
             50-60                1.8                  0.41
             40-50                8.5                  0.36
             30-40               16.0                  0.31
             20-30               22.3                  0.27
             10-20               26.9                  0.25
              0-10               27.7                  0.25
        The ice edge is at  71.42  degrees north.

        Input parameters
  Fraction of solar constant 1.
        A= 204        B= 2.17
        C= 3.8
Ice albedo=  .62 Changes at -10  Deg C
```

The above information corresponds to what one would think it should be. In order to show correctness, I will change each of the variables and make an educated guess about the outcome.

First I will change a. I will make a very small (25) and the zones should warm up considerably. This is because, when a is small, there is a much smaller amount of radiation lost to space (it stays on earth). With a set to 25, the output is...

```
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                    R E S U L T S
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
         Zone              Temperature           Albedo
      =============        ===========           ======
            80-90            72.8                  0.50
            70-80            73.7                  0.50
            60-70            78.0                  0.45
            50-60            84.6                  0.41
            40-50            91.3                  0.36
            30-40            98.9                  0.31
            20-30           105.2                  0.27
            10-20           109.7                  0.25
             0-10           110.6                  0.25
      The ice edge is at  0  degrees north.

      Input parameters
  Fraction of solar constant 1.
      A= 25       B= 2.17
      C= 3.8
 Ice albedo=  .62 Changes at -10  Deg C
```

The above figures correspond to my prediction. Now if a is very large, say 1000, then the planet should be ice covered and very cold because there is no radiation staying on earth. I will not show all output so that I may save a tree but I will say that the equator is at -396.0 Degrees Celsius (which is below absolute zero).

Now to look at b. Changing b should have the same effect as changing a because the formula for long wave radiation (R) lost to space is R = a + b * Temperature(zone). The difference is that it takes a smaller adjustment of b to get the same results as a large change in a. For example, if a stays at 204, b must be changed to roughly .35 a factor of 6.2 whereas a was changed by a factor of 8.16. However the larger b that is chosen means there is lass of a difference between zones. In fact as b goes to infinity, all zones tend to 0 Degrees C. This is because b is a coefficient.

I will now analyze c. Recall that c stands for the transport coefficient. That means that if I put a larger value in for c, heat will be shared by neighboring zones more. This means the zonal temperatures will be closer to the mean temperature. When the model is run with c = 49, the temperatures range from 12.9 to 17.3. With a small c value, the temperature differences between zones should grow. When c = .1 Temperature range is -60.7 to 47.8. Also recall that with the default values the range is -13.5 to 27.7.

Now I will predict what will happen with changes in aice. The albedo of ice is what aice stands for. Albedo is the ability of something to reflect light and heat. The default value of aice is .62. This means that 62% of the heat that hits ice is reflected. If this number were to grow, more heat would be reflected and lost, causing a drop in temperature. If the number is lowered it causes an increase in temperature. One thing to point out though is that since it is that albedo of ice, there should be no (or very little) change in the zones that aren't covered with ice. For example, if aice = .9 then the temperature at the north pole is -22.5 (colder than before) and the temperature at the equator is 26.8 which is very close to the default simulation. If aice drops to nearly zero, i.e. .1, then it is expected that the ice areas will warm up and possibly not be ice covered any more. This is because with a low ice albedo, less heat is reflected thus more heat stays around. When aice = .1 there is no surface of the earth that is ice covered. The north pole is at -9.7 degrees Celsius so it is almost ice covered.

The next variable to play with is tcrit. This variable represents the temperature at which the surface is covered with ice. Increasing this value will cause the average surface temperature to fall. This is because the albedo of ice is greater than that of ground, causing more heat to be reflected away from Earth. Decreasing tcrit should cause an increase in average surface temperature for the same reasons as above. For example, when tcrit = 0, the ice edge is at 55.7 degrees. When tcrit = -10, the ice edge is at 71.42 degrees north. This change in ice line causes more of the earth to have a higher albedo, reflecting more heat.

Finally, we get to aland(). Changing aland for ice covered latitudes doesn't matter because the albedo of ice should be used there. However, changing aland for latitudes not covered in ice should have the same effects as changing aice has on ice covered latitudes. For example, say the equatorial zone has an albedo of .6 rather than the default .254. This causes the temperature there to be a balmy -4.6 degrees. In fact, the point where the equator freezes is when its albedo is roughly .68. On the other hand, if aland is decreased then the zone should warm up.

One last variable to consider is the fraction of the solar constant, sx. All examples given have been where sx = 1. If sx is less than one then the earth doesn't get as much sun and the planet gets colder. If sx is greater than one then the planet gets more sun and gets warmer. Using the default values, and sx = .9 and sx = 1.1 yields the following output...

```
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                R E S U L T S
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
           Zone                  Temperature             Albedo
        =============         ===========               ======
              80-90              -22.3                     0.62
              70-80              -21.7                     0.62
              60-70              -19.9                     0.62
              50-60               -8.5                     0.41
              40-50               -2.5                     0.36
              30-40                4.3                     0.31
              20-30               10.0                     0.27
              10-20               14.1                     0.25
               0-10               14.9                     0.25
        The ice edge is at  56.3  degrees north.

        Input parameters
  Fraction of solar constant .89
        A= 204        B= 2.17
        C= 3.8
 Ice albedo=  .62 Changes at -10  Deg C
```

```
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                                R E S U L T S
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
           Zone                  Temperature             Albedo
        =============         ===========               ======
              80-90               -1.3                     0.50
              70-80               -0.3                     0.50
              60-70                4.5                     0.45
              50-60               11.8                     0.41
              40-50               19.1                     0.36
              30-40               27.5                     0.31
              20-30               34.4                     0.27
              10-20               39.4                     0.25
               0-10               40.3                     0.25
        The ice edge is at  0  degrees north.

        Input parameters
  Fraction of solar constant 1.1
        A= 204        B= 2.17
        C= 3.8
 Ice albedo=  .62 Changes at -10  Deg C
```

By showing that modifying the program's variables leads to predicted results and the default results comply with current knowledge, it is safe to assume that the model is correct. The only thing left to do is discus the first two questions on pages 82-83 in "A Climate Modelling Primer" by K. McGuffie & A. Henderson-Sellers. Question 1 (a) asks, "What fraction of solar constant \glaciates the earth?" I found that somewhere between 78.917% and 78.918% a large leap is made and the earth is glaciated. I say a large leap because when sx = .78918, the ice line is at 25 degrees north, but at sx = .78917 the equatorial zone has a temperature of -42.9 degrees Celsius. For question 2(a) let a = 225, b = 1.1, c = 8, tcrit = -15, aice = .5, aland(i) = aland(i) - .1

Then sx must be between 90.141% and 90.142%. At sx = .90142, the ice line is at 35.0 degrees north. But at sx = .90141, the equatorial zone temperature is -60.4

Exercise 2(a) calls for different K values. Remember that in this model, the variable c and the value K are the same. A good way to describe the effects of a variable change on the climate is by the ice line. When K = 3.81, the ice line is at 71.49 Degrees North, but when K = 3.74, the ice line is at 71.12. So a .7 change in K caused a .37 degree shift in the ice line. That is roughly .5 degrees per 1 unit increase in K at in the area of 3.88. The climate isn't extremely sensitive to the K value. Obviously it does make a difference otherwise it would have been left out of the equations, but a large change in K causes only a small change in the climate. Exercise 2(b) Asks for a prediction of the volatility of the climate at small and large values of K. I predict that as K gets smaller the climate gets less sensitive to changes in the solar constant. But with large values in K, a small change in the solar constant can make a large climactic shift. Using the model and a K value of .1, sx can be nearly .6 before the planet glaciates. But with K value of 49.9, the planet glaciates at a little less than .8. When K is the default value recall that the glaciated with 78% of the solar constant and that was with K = 3.8. So for K's between about 3 and 50, not much changes in terms of the amount of solar constant needed to glaciates the earth.