# *Global Warming Zonal Temp - Energy Balance Model*

Energy flows into Earth through radiation from the Sun and out of Earth by reflection and radiation. There are latitudinal variations. The flow of energy into Earth and the flow of energy out of Earth must be equal if Earth is to maintain a stable temperature.

$H_0$ is the extraterrestial solar flux ($w/m^2$). In the zonal model, we need to be able to calculate the total energy received from the sun per unit time. This is given by $\pi R^2 H_0$. The average extraterrestrial solar flux over the entire surface can by calculated by $H_0/4$.

**Anthropogenic Global Warming Simulation:**

The long wavelength flux to space, H+(T,c ) can be approximated by a first order expansion in the surface air temperature and the logarithm of the atmospheric cargon dioxide concentration, c.

H+(T,c) = Aco2 + Bco2 T - Cco2 ln(c/co)

We will assume that Aco2, Bco2, and Cco2 ln(co/co) are a component parts of our general model for this point in time. We will then explicitly separate out the Cco2 ln(c/co) contribution.

There are a number of estimates for Cco2. The preindustrial atmospheric CO2 concentration is 280 ppm. Today's value of 370 ppm

**Data Constants:**

SC: Solar Constant (W/m2),

A & B: Long Wave Radiation Heat Loss (Greenhouse) A (W/m2), B(W/m2/C) $R_{loss} = A + B \times T$

C: Transport Coefficient (Conductivity between zones) C(W/m2/C)

Tcrit: Temperature at which land becomes covered with snow and/or water turns to ice

Aice; Ice Albedo, SunWt: Annual mean radiation at lattitude W/m2

CO2 Global Warming Forcing = 5.7 W/m2

$SC := 1370$ $B := 2.17$ $C := 3.87$ $CO2 := 5.7$ $A := 204 - CO2$ $Tcrit := -10$

$SCfrac := 0.9$ $\alpha_{ice} := 0.62$ $\alpha_{land} := 0.3$ $c_o := 200$ $c_x := 400$

max_tilt := 23.5 days_in_year := 365 hours_in_day := 24 zonal_degrees := 360

Pole_Temp_Diff_Dat := −42.3 Glob_Avg_Temp := 14.9 $Cgw := CO2 \cdot \ln\left(\frac{400}{c_o}\right)$

**Read NCEP surface air temperature (annual, zonal mean, deg C) and Sim Temp**

TempDat := READPRN("NCEP_air_zonal.dat") rows(TempDat) = 72

TempSimToday := READPRN("FinalTempSim.txt")

**Read Albedo Data: Earth Radiation Budget Experiment (ERBE) 1986 - 1989**

AlbedoLat := READPRN("Avg_Albedo_Latitude.txt") rows(AlbedoLat) = 72

$lats := 36$ $lat := 1..lats$ $Init\_T_{lats} := 100$ $LatA := AlbedoLat^{\langle 1 \rangle}$ $Albedo := AlbedoLat^{\langle 2 \rangle}$

$zonal\_width := \frac{90}{lats}$ $ZoneLat_{lat} := \frac{zonal\_width}{2} + (lats - lat) \cdot zonal\_width$

$delta\_rad := \frac{\pi}{lats}$ $zones_{lat} := \frac{zonal\_width}{2} + (lat - 1) \cdot zonal\_width$

$lats\_rad := \frac{lats \cdot \pi}{180}$ $max\_steps := 100$

```
reverse(V) := | R ← rows(V)
              | for r ∈ 1..R
              |   Rev_r ← V_(R+1−r)
              | Rev
```

Fraction of the surface of sphere in each latitude zone

$lats\_frac := (\sin(lats\_rad + delta\_rad) - \sin(lats\_rad - delta\_rad))$

**Daily rotation of earth reduces solar constant by distributing sun energy along a zonal band**

$$total\_solar := \left| \begin{array}{l} total\_solar \leftarrow 0 \\ \text{for } hour \in 1 .. hours\_in\_day \\ \quad \left| \begin{array}{l} noon\_angle \leftarrow zonal\_degrees \cdot \dfrac{hour}{hours\_in\_day} \\ \text{for } longitude \in 1 .. zonal\_degrees \\ \quad \left| \begin{array}{l} sun\_angle \leftarrow longitude - noon\_angle \\ MaxAngle \leftarrow if\left( \cos\left(\dfrac{\pi \cdot sun\_angle}{180}\right) > 0, \cos\left(\dfrac{\pi \cdot sun\_angle}{180}\right), 0 \right) \\ total\_solar \leftarrow total\_solar + SC \cdot MaxAngle \end{array} \right. \end{array} \right. \\ total\_solar \end{array} \right.$$

$$FlipAug(V) := \left| \begin{array}{l} R \leftarrow rows(V) \\ \text{for } r \in 1 .. R \\ \quad \left| \begin{array}{l} VF_r \leftarrow V_r \\ VF_{R+r} \leftarrow V_{R+1-r} \end{array} \right. \\ VF \end{array} \right.$$

$$solar\_constant := \frac{total\_solar}{hours\_in\_day \cdot zonal\_degrees}$$

**Annual Insolation: Accumulate normalized insolation through a year**

$Insolation_{lat} := 0$ $\qquad$ $Init\_T := FlipAug(Init\_T)$

$$insolation := \left| \begin{array}{l} I \leftarrow Insolation \\ \text{for } day \in 1 .. days\_in\_year \\ \quad \left| \begin{array}{l} tilt \leftarrow max\_tilt \cdot \cos\left(2 \cdot \dfrac{\pi \cdot day}{days\_in\_year}\right) \\ \text{for } j \in 1 .. lats \\ \quad \left| \begin{array}{l} zenith \leftarrow if\left(zones_j + tilt < 90, zones_j + tilt, 90\right) \\ I_j \leftarrow I_j + \cos\left(zenith \cdot \dfrac{\pi}{180}\right) \end{array} \right. \end{array} \right. \\ \dfrac{solar\_constant \cdot reverse(I)}{days\_in\_year} \end{array} \right.$$

$latsS := 2 \cdot lats$ $\quad$ $latS := 1 .. latsS$ $\quad$ $insolation := FlipAug(insolation)$ $\quad$ $ZoneLat := FlipAug(ZoneLat)$

$$SumCos := \sum \cos\left(ZoneLat \cdot \frac{\pi}{180}\right) \qquad T\_Cos_{latS} := Init\_T_{latS} \cdot \cos\left(ZoneLat_{latS} \cdot \frac{\pi}{180}\right)$$

$$Mean\_T := \sum T\_Cos \cdot \frac{1}{SumCos} \qquad Temp_{init} := \frac{\overrightarrow{[insolation \cdot (1 - Albedo) + C \cdot Mean\_T - A - Cgw]}}{B + C}$$

$Mean\_T = 4.362$ $\qquad$ $mean(Temp_{init}) = 5.462$ $\qquad$ $Step_{latS} := 0$

$tol\_temp\_diff := 1$

$$\text{Final\_TA(Albedo)} := \begin{array}{|l} \text{step} \leftarrow 2 \\ \text{max\_temp\_diff} \leftarrow 100 \\ \text{Temp} \leftarrow \text{Temp}_{init} \\ \text{while step} < \text{max\_steps} \wedge \text{max\_temp\_diff} > \text{tol\_temp\_diff} \\ \quad \begin{array}{|l} \text{step} \leftarrow \text{step} + 1 \\ \text{Temp\_old} \leftarrow \text{Temp} \\ \text{Mean\_T}_{step} \leftarrow \sum \overrightarrow{\left(\text{Temp}\cdot\cos\left(\text{ZoneLat}\cdot\frac{\pi}{180}\right)\right)}\cdot\frac{1}{\text{SumCos}} \\ \text{Temp} \leftarrow \overrightarrow{\left[\text{insolation}\cdot(1-\text{Albedo}) + \text{C}\cdot\text{Mean\_T}_{step} - \text{A} - \text{Cgw}\right]}\cdot\frac{1}{(\text{B}+\text{C})} \\ \text{for lat} \in 1..\text{latsS} \\ \quad \begin{array}{|l} \text{Albedo}_{lat} \leftarrow \alpha_{ice} \text{ if } \text{Temp}_{lat} < \text{Tcrit} \wedge \text{Albedo}_{lat} < \alpha_{land} \\ \text{Albedo}_{lat} \leftarrow \alpha_{land} \text{ if } \text{Temp}_{lat} > \text{Tcrit} \wedge \text{Albedo}_{lat} < \alpha_{land} \\ \text{Step}_{lat} \leftarrow \text{step} \end{array} \\ \text{max\_temp\_diff} \leftarrow \max\left[\left|\overrightarrow{(\text{Temp\_old} - \text{Temp})}\right|\right] \end{array} \\ \text{Final\_T} \leftarrow \overrightarrow{\frac{\text{insolation}\cdot(1-\text{Albedo}) + \text{C}\cdot\text{Mean\_T}_{step} - \text{A} - \text{Cgw}}{\text{B}+\text{C}}} \\ \text{Final\_T} \leftarrow \text{augment(Final\_T, Albedo, Step)} \end{array}$$

$\text{FTA} := \text{Final\_TA(Albedo)}$ $\qquad$ $\text{FTA}_{1,3} = 12$ $\qquad$ $\text{Final\_Temp} := \text{FTA}^{\langle 1 \rangle}$

$\text{mean(Final\_Temp)} = 4.489$ $\qquad$ $\text{mean(TempDat)} = 3.089$ $\qquad$ $\text{ALBEDO} := \text{FTA}^{\langle 2 \rangle}$

$\text{NPole\_Eq\_Diff} := \text{Final\_Temp}_1 - \text{Final\_Temp}_{lats}$ $\qquad$ $\text{NPole\_Eq\_Diff} = -44.217$

**North's 1-D Effusive EBM Analytic Model (Magenta Plots)**

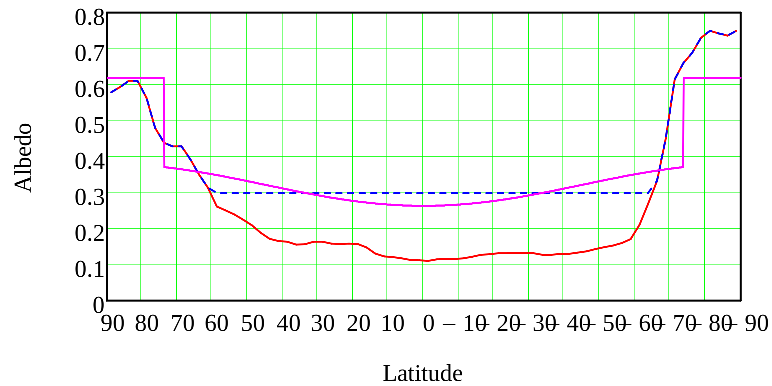
To is the planetary, globally averaged temperature, T2 is 2/3 of the Temp difference from the poles to equator, Tpe. The ice sheet edge (T = -10C) is above 73.74$^{o}$, with ice albedo, $\alpha_{ice}$.

$T_o := 14.9$ $\qquad$ $T_{pe} := -42.3$ $\qquad$ $T_2 := \frac{2}{3}\cdot T_{pe}$ $\qquad$ $x_s := 0.96$

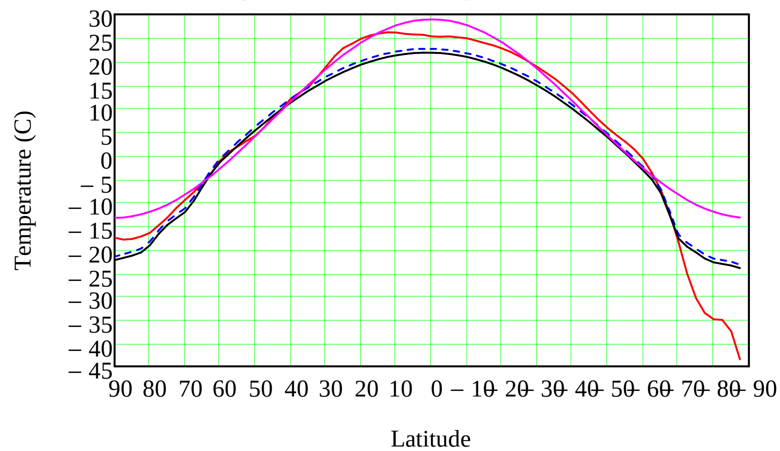
$\alpha_o := 0.303$ $\qquad$ $\alpha_2 := 0.0779$ $\qquad$ $\alpha(\theta) := \text{if}\left(|\theta| < 73.7, \alpha_o + \alpha_2\cdot\text{Leg}\left(2, \sin\left(\frac{\theta\cdot\pi}{180}\right)\right), \alpha_{ice}\right)$

$T_{North}(\theta) := T_o + T_2\cdot\text{Leg}\left(2, \sin\left(\frac{\theta\cdot\pi}{180}\right)\right)$ $\qquad$ $T_{North}(90) = -13.3$ $\qquad$ $T_{North}(73.7) = -9.968$

Albedo Data & Simulation Albedo (Dotted)




Avg. Global & Sim Temp (Dotted) vs. Lat.




WRITEPRN("FinalTempSim.txt") := Final_Temp

**<u>Climate Sensitivity: Anthrotropic Global Warming from Doubled CO2 Concentration</u>**

$AGW := \text{mean}(Final\_Temp - TempSimToday) \qquad AGW = 0.8$

Taking the central value of the likely range of climate sensitivities of 3 oC (the temperature rise from doubling atmospheric CO2) the equilibrium temperature rise is expected to be:

Temp rise = ln([CO2]2/[CO2]1)*3/ln2

where [CO2]1 is the starting [CO2] level, [CO2]2 is the end [CO2] level, 3 is the climate sensitivity and ln2 refers to the doubling.

$$\Delta T_{CO2}(CO2) := \ln\left(\frac{CO2}{c_o}\right)\cdot\frac{3}{\ln(2)}$$

H2O and CO2 have the same number of IR active vibrations - 3. An absorption band at a given frequency is due to a specific vibration. For example the 650cm-1 CO2 absorption is due to the (doubly degenerate) bending mode. So more asymmetry in a molecule does not mean more absorption at a given wavelength. It usually means more wavelengths at which it absorbs.

However asymmetry will complicate the rotational-fine structure of a particular IR absorption, however H2O's rotational fine structure will be quite dispersed because of its light mass (18 compared to CO2's 44)

**<u>Radiative Forcing</u>**

The radiative forcing for CO2 (this is the forcing at the tropopause, not the surface, as described in Myhre et al 1998 and later papers) is

$k := 5.35 \cdot \frac{W}{m^2}$ $\quad F_{CO2}(CO2) := k \ln\left(\frac{CO2}{c_o}\right)$ $\quad F_{CO2}(2 \cdot c_o) = 3.708 \frac{kg}{s^3}$

Where the constant k (derived from line-by-line radiative transfer codes) C0 are the final and initial $CO_2$ concentrations.

Climate sensitivity is the temperature response of the system per unit forcing. In other words, a high climate sensitivity means that it is very easy to change the global mean temperature, while a very low sensitivity would require an enormous forcing to get that same change. In the easiest case, we'll consider what happens when you only increase some forcing (say double $CO_2$) and allow the outgoing radiation to increase (according to the Stefan-Boltzmann law) to re-establish a new radiative equilibrium. Here, nothing else changes with the climate state (no cloud cover changes, no ice melts, etc) except for our forcing. This is the so-called Planck response.

In a simple way, we can assume that the surface and emission temperature are linearly related, in which case the Planck-only feedback response can be computed as the inverse of the derivative of Stefan-Boltzmann with respect to temperature,

$$\lambda_{planck} = \left[\frac {\partial\left(\sigma T^{4}_{eff}\right)}{\partial T_{s}}\right]^{-1}$$

Which equals,

$$(4 \sigma T^{3}_{eff})^{-1} = 0.27 K(W m^{-2})^{-1}$$

The temperature response can then be linearly related to a forcing

$$\Delta T = \lambda F$$

To compute a radiative forcing for an increase in solar irradiance, we do

$$F_{solar} = S_{0} * (percent change/100)*(1/4)*(0.7)$$

where the 1/4 and 0.7 factor account for the geometry and albedo of the Earth, respectively. Depending on how radiative forcing is defined, this number can often be reduced further to account for ozone absorption of UV or other effects, but in general the forcing due to a realistic change in solar increase is very small. It follows that it would take about a **22 W/m2 change in solar irradiance to produce a 1 K change in global temperature**. This is actually a very stable climate. This also demonstrates the intellectual bankruptcy of those who claim that the solar trend over the last half century (which has pretty much been a flat-line when you remove the 11-year oscillatory signal) is responsible for most of the observed late 20th century warming, and simultaneously argue for a low sensitivity.