EOSC 112: Lab1b – Week of September 17
Greenhouse effect (partially absorbing atmosphere).

Objective: Investigate the impact of absorption, albedo, and solar constant on the surface temperature of the planet. How do changes in albedo and absorption translate into surface temperature changes?

Procedure: *lab1b.xls* is an Excel spreadsheet that takes as input (grey boxes), values for planetary albedo A (A3), atmospheric absorption *absorp* (A7), and solar constant (A11). The output is given in the yellow boxes (fluxes, units: $\mathrm{W\,m^{-2}}$), and temperatures (blue boxes, units: K). Recall that the fluxes are defined in the following figure:

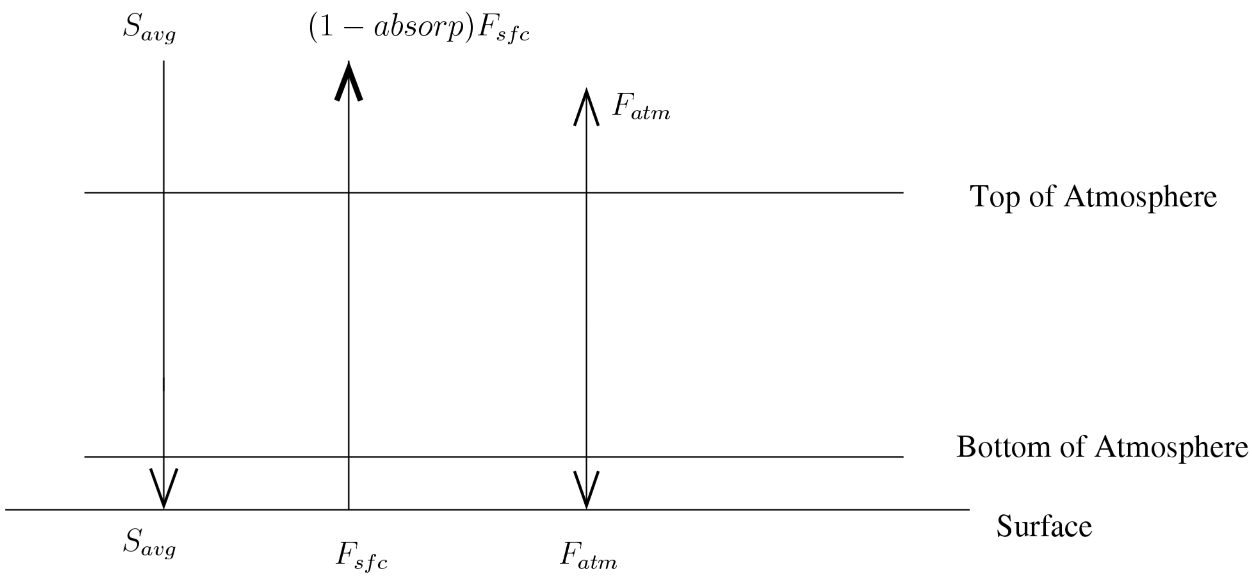

Figure 1: Short (S_{avg}) and longwave (F_{atm}) fluxes for a partially absorbing atmosphere. (Units: $\mathrm{W\,m^{-2}}$). Note that now some of F_{atm} makes it through the top of the atmosphere. (For example, if $absorp = 0.8$, then 20% of F_{sfc} makes it to outer space.)

and these equations:

$$F_{atm} = \frac{absorp}{2-absorp} S_{avg} \tag{1}$$

$$F_{sfc} = \frac{2}{2-absorp} S_{avg} \tag{2}$$

From Equation (2) we can solve for T_{sfc}, the surface temperature:

$$T_{sfc} = \left(\frac{2S_{avg}}{\sigma(2-absorp)}\right)^{1/4} \tag{3}$$

S_{avg}, F_{sfc}, F_{atm} and T_{sfc} are reported in the boxes (A15), (A19), (A23) and (D24).

Questions: Use the spreadsheet to answer the following:

Q1: Enter an *absorp*=0.8, S=1370, Albedo=0.3, (values close to current climate). Add up the fluxes by hand to show F_{sfc} balances the flux from sun (S_{avg} and atmosphere F_{atm}). Also confirm by hand that $\sigma T_{sfc}^4 = F_{sfc}$.

```
>>> Savg=239.75
>>> Fatm=159.8333
>>> Savg+Fatm
399.58330000000001

>>> 5.67e-8*289.7384**4.
399.58326295934154
>>> Tsfc=289.7384
>>> 5.67e-8*Tsfc**4.
399.58326295934154
```

Q2: Increase the atmospheric absorption until the value of F_{sfc} is $4 \pm 0.5\ \mathrm{W\,m^{-2}}$ bigger than the value you found in Q1. Report the new value of the absorption, as well as it's change from the previous value in per cent (i.e. 100.*(new - old)/old)

Need F_{sfc} in the range:

```
>>> 399.5833 + 3.5
403.08330000000001
>>> 399.5833 + 4.5
404.08330000000001
```

Trial and error should produce *absorp* values in the range:

```
0.81041 - 0.81336

(They could also invert the spreadsheet equation and solve it):

>>> Fsfc=404.08330000000001
>>> 2. - (2.*Savg/Fsfc)
0.81336348223250021

Percentage changes in the range 1.3 - 1.67%:

>>> (0.81041958324743302 - 0.8)/.8
0.013024479059291216


>>> (0.81336348223250021 - 0.8)/.8
0.01670435279062521
```

Q3: For the absorption increase in Q2, what is the change in T_{sfc} (new value and change in previous value in per cent). *Note that by the year 2050, the longwave flux leaving the top of the atmosphere will be reduced by 4* $\mathrm{W\,m^{-2}}$ *due to the human-produced greenhouse effect increasing* F_{sfc} *by about that amount.*

```
absorp of 0.8104 gives Tsfc=290.3696


absorp of .81336 gives Tsfc=290.5505

percentage and absolute changes for these two values:

>>> (290.3696 - 289.7384)/289.7384
0.0021785168966211533 = 0.2%
>>> (290.3696 - 289.7384)
0.6311999999997844 K
>>> (290.5505 - 289.7384)/289.7384
0.0028028732125254599 = .28%
>>> (290.5505 - 289.7384)
0.8120999999998672 K
>>>
```

Q4: You've been hired to counteract the 4 $\mathrm{W\,m^{-2}}$ greenhouse warming by increasing the planetary albedo using white plastic sheets. Put in the extra absorption you found in Q2, and then increase the albedo until you return F_{sfc} to its original value (value with *absorp=0.8*). Report the new albedo and its change from 0.3:

```
Savg needs to be in the range 237.6721 - 237.080763 W/m/m
to return Fsfc to 399.5833 W/m/m.

This means an albedo range for the answer of:
0.3060667 - 0.307793

or in percent:

>>> A=0.3060667
>>> (A-0.3)/.3
0.020222333333333453=2%
>>> A=0.307793
>>> (A-0.3)/.3
0.025976666666666648=2.6%
```

```
They could find this either by playing with A=albedo or by solving
the spreadsheet equation:

>>> Fsfc=399.5833
>>> absorp=0.8104
>>> Savg=(2. - absorp)/2.*Fsfc
237.67214684000001

solving Savg for albedo:

>>> Savg=237.67214684000001
>>> A=1. - (4.*Savg/S)
>>> A
0.30606672455474448


or:

>>> absorp=.81336
>>> Savg=(2. - absorp)/2.*Fsfc
>>> Savg
237.08076355600002
>>> A=1. - (4.*Savg/S)
>>> A
0.30779339107737225
```