Exercise 2 UV Radiation

1)

Assuming we have ozone hole conditions over middle latitudes, calculate the **UV Index** in Zurich at local **noon on 1 June** 2020

assuming clear sky conditions for total column **ozone of 94 DU** (minimum of 2020 antarctic ozone hole) and

compare the results to standard conditions at Zurich.

δ = 59.24

```
# solar elevation angle by https://www.esrl.noaa.gov/gmd/grad/solcalc/azel.html
δ = 59.24
```

θ = 30.759999999999998

```
# solar zenith angle
θ = 90 - δ
```

```
using Statistics
```

```
using DataFrames
```

```
using DelimitedFiles
```

```
using NumericalIntegration
```

```
using Plots
```

in1.inp

```
data_files_path /opt/libRadtran/data/
atmosphere_file /opt/libRadtran/data/atmmod/afglus.dat
source solar /opt/libRadtran/data/solar_flux/atlas_plus_modtran
mol_modify O3 94. DU # Set ozone column
day_of_year 153 # Correct for Earth- Sun distance
albedo 0.2 # Surface albedo
```

```
sza 30.8 # Solar zenith angle
rte_solver disort # Radiative transfer equation solver
number_of_streams 6 # Number of streams
wavelength 299.0 341.0 # Wavelength range [nm]
```

Assume standard total ozone column over Zurich to be 310 DU.

ref: **MeteoSwiss**

in2.inp

```
mol_modify O3 310 DU # Set ozone column
```

```
sp1 = DataFrame(readdlm("out1.csv", '\t'), ["Wavelength [nm]", "Direct beam irradiance [mW m⁻² nm⁻¹]", "Diffuse down irradiance [mW m⁻² nm⁻¹]"]);
```

	Wavelength [nm]	Direct beam irradiance [mW m^{-2} nm^{-1}]	Diffuse down irradiance [mW m^{-2} nm^{-1}]	Total irradiance [W m^{-2} nm^{-1}]
1	299.0	4.09936	5.51126	0.00961062
2	299.05	41.7061	56.0706	0.0977767
3	299.1	40.4432	54.3728	0.094816
4	299.15	38.4184	51.6843	0.0901027
5	299.2	35.467	47.7138	0.0831807
6	299.25	34.5955	46.5413	0.0811368
7	299.3	36.1641	48.6861	0.0848502
8	299.35	31.1684	41.9607	0.0731291
9	299.4	24.07	32.4044	0.0564744
10	299.45	20.8687	28.1163	0.048985

```
begin
    sp1["Total irradiance [W m⁻² nm⁻¹]"] = (sp1["Direct beam irradiance [mW m⁻² nm⁻¹]"] .+ sp1["Diffuse down irradiance [mW m⁻² nm⁻¹]"]) ./ 1000
    sp1
end
```

```
Float64[0.00503688, 0.00512443, 0.00496926, 0.00511523, 0.00472227, 0.00460623
```

```
begin
    sp2 = DataFrame(readdlm("out2.csv", '\t'), ["Wavelength [nm]", "Direct beam irradiance [mW m⁻² nm⁻¹]", "Diffuse down irradiance [mW m⁻² nm⁻¹]"])
    sp2["Total irradiance [W m⁻² nm⁻¹]"] = (sp2["Direct beam irradiance [mW m⁻² nm⁻¹]"] .+ sp2["Diffuse down irradiance [mW m⁻² nm⁻¹]"]) ./ 1000
end
```

```
heaviside (generic function with 1 method)
```

```
function heaviside(t)
   0.5 * (sign(t) + 1)
end
```

```
interval (generic function with 1 method)
```

```
function interval(t, a, b)
   heaviside(t-a) - heaviside(t-b)
end
```

```
erythemaAS (generic function with 1 method)
```

```
function erythemaAS(λ)
    1. .* interval(λ, 250,298) +
    10^(0.094*(298-λ)) .* interval(λ, 298,328) +
    10^(0.015*(140-λ)) .* interval(λ, 328,400)
end
```

```
0.5613782827215871
```

```
begin
    eryWeiIrr1 = sp1["Total irradiance [W m⁻² nm⁻¹]"] .* erythemaAS.(sp1["Wavelength [nm]"])
    Eery1 = integrate(sp1["Wavelength [nm]"], eryWeiIrr1)
end
```

```
0.1853562421006384
```

```
begin
    eryWeiIrr2 = sp2["Total irradiance [W m⁻² nm⁻¹]"] .* erythemaAS.(sp2["Wavelength [nm]"])
    Eery2 = integrate(sp2["Wavelength [nm]"], eryWeiIrr2)
end
```

```
(22.46, 7.41)
```

```
UVI1, UVI2 = round(Eery1*40, digits=2), round(Eery2*40, digits=2)
```

The UV index in the first situation is ***22.46****, which is around 3 times of the UV index of* ***7.41*** *in the standard situation.*

2)

Estimate the impact of the California Forest fires on the erythemal weighted irradiance on 10 September. Use aerosol info from **Aeronet site Monterey** in30.inp

```
data_files_path /opt/libRadtran/data/
atmosphere_file /opt/libRadtran/data/atmmod/afglus.dat
source solar /opt/libRadtran/data/solar_flux/atlas_plus_modtran

day_of_year 254 # Correct for Earth- Sun distance
albedo 0.2 # Surface albedo
sza 35.3 # Solar zenith angle at 19:00 UTC
rte_solver disort # Radiative transfer equation solver
number_of_streams 6 # Number of streams
wavelength 299.0 341.0 # Wavelength range [nm]
```

in3.inp

```
aerosol_vulcan 1 # Aerosol type above 2km
aerosol_haze 6 # Aerosol type below 2km
aerosol_season 2 # Fall-winter profile.
aerosol_visibility 20.0 # Visibility
aerosol_modify tau set 2.8
```

0.14406499340681791

```
begin
    sp30 = spec("out30.csv");
    eryWeiIrr30 = sp30[2] .* erythemaAS.(sp30[1])
    Eery30 = integrate(sp30[1], eryWeiIrr30)
end
```

0.07905105089467586

```
begin
    sp3 = spec("out3.csv");
    eryWeiIrr3 = sp3[2] .* erythemaAS.(sp3[1])
    Eery3 = integrate(sp3[1], eryWeiIrr3)
end
```

imp = 0.5487179711413137

```
imp = Eery3 / Eery30
```

California forest fires reduced the the erythemal weighted irradiance on 10 September to ***55% of its normal level****.*

3)

Calculate the spectral irradiance (290 to 400 nm) for several albedo values between 0.04 (grass), and 0.9 (fresh snow) and

two total column ozone amounts (for example 300 and 500 DU).

Plot graphically (ratio relative to grass albedo) and discuss the results.

in4.inp

```
data_files_path /opt/libRadtran/data/
atmosphere_file /opt/libRadtran/data/atmmod/afglus.dat
source solar /opt/libRadtran/data/solar_flux/atlas_plus_modtran
mol_modify O3 300. DU # Set ozone column
day_of_year 170 # Correct for Earth- Sun distance
albedo 0.04 # surface albedo
sza 32 # Solar zenith angle
rte_solver disort # Radiative transfer equation solver
number_of_streams 6 # Number of streams
wavelength 290.0 400.0 # Wavelength range [nm]
```

in5.inp

```
albedo 0.4 # Surface albedo
```

in6.inp

```
albedo 0.9 # Surface albedo
```

in7.inp

```
mol_modify O3 400. DU # Set ozone column
albedo 0.04 # surface albedo
```

in8.inp

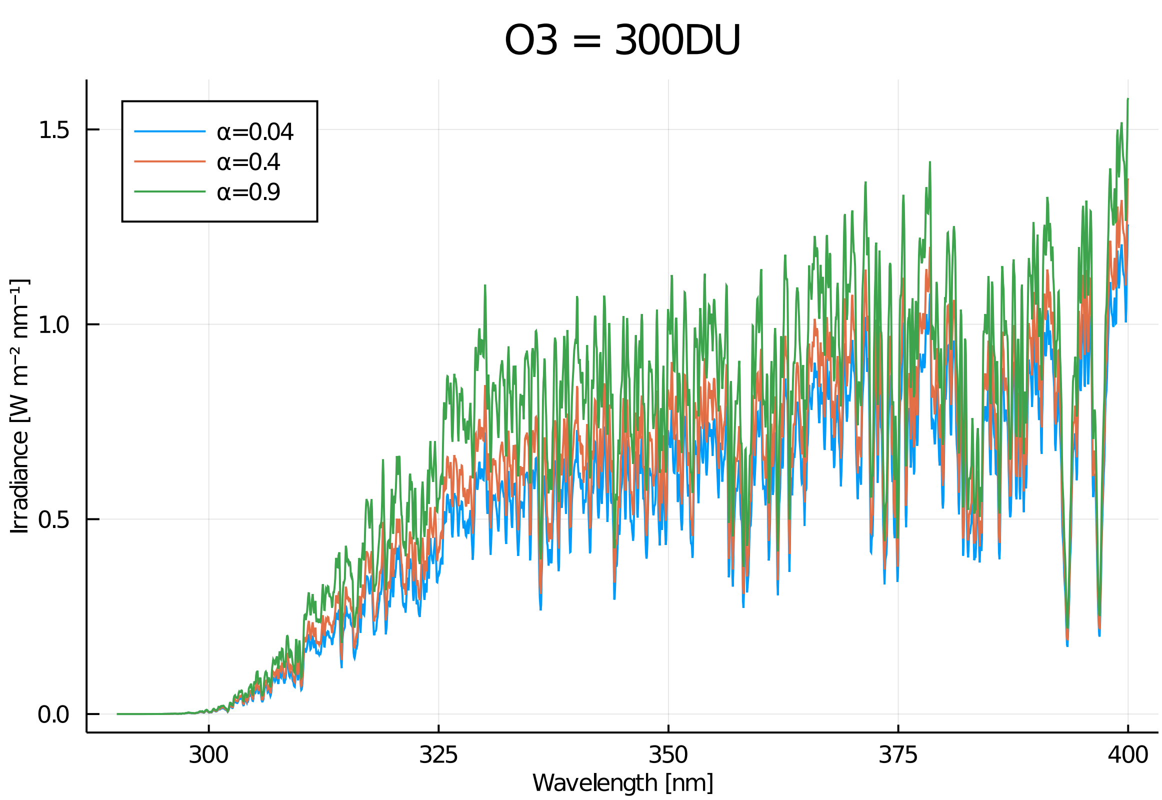
```
mol_modify O3 500. DU # Set ozone column
albedo 0.04 # surface albedo
```

spec (generic function with 1 method)

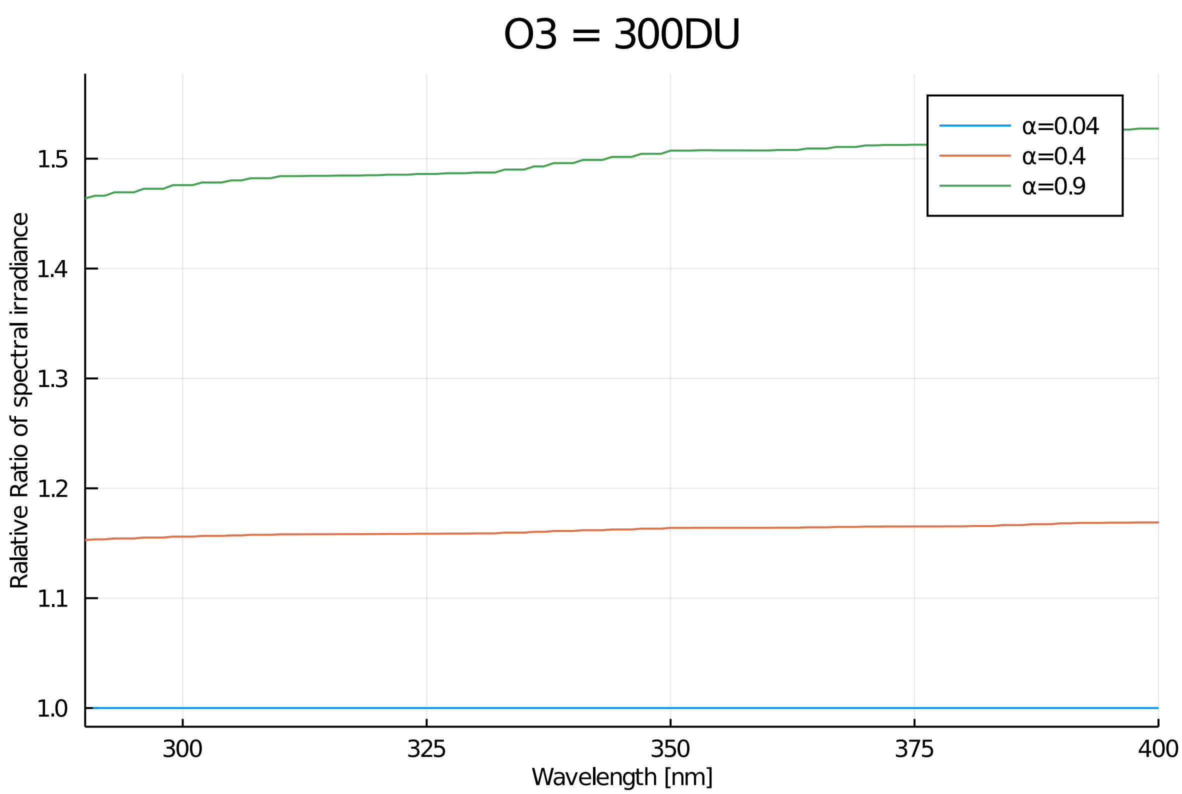
```julia
function spec(fnam)
    sp = DataFrame(readdlm(fnam, '\t'), ["Wavelength [nm]", "Direct beam irradiance [mW m⁻² nm⁻¹]", "Diffuse down irradiance [mW m⁻² nm⁻¹]"])
    sp["Total irradiance [W m⁻² nm⁻¹]"] = (sp["Direct beam irradiance [mW m⁻² nm⁻¹]"] .+ sp["Diffuse down irradiance [mW m⁻² nm⁻¹]"]) ./ 1000
    x = sp["Wavelength [nm]"]
    y = sp["Total irradiance [W m⁻² nm⁻¹]"]
    return x, y
end
```

(Float64[290.0, 290.05, 290.1, 290.15, 290.2, 290.25, 290.3, 290.35, 290.4,

```julia
begin
    sp4 = spec("out4.csv");
    sp5 = spec("out5.csv");
    sp6 = spec("out6.csv");
    sp7 = spec("out7.csv");
    sp8 = spec("out8.csv");
end
```



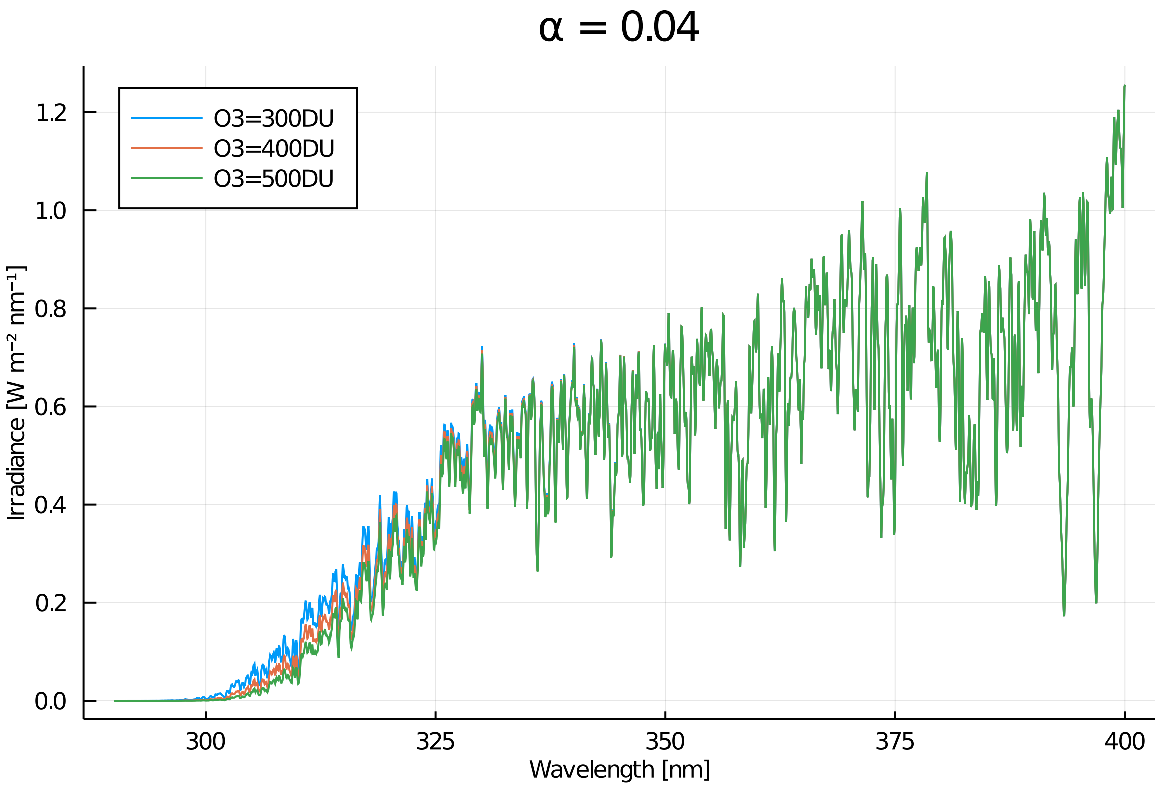
```
begin
    p1 = plot(sp4[1], sp4[2], label="α=0.04", leg=:topleft,
              title="O3 = 300DU", labelfontsize=8,
              xlabel="Wavelength [nm]", ylabel="Irradiance [W m⁻² nm⁻¹]", )
    plot!(sp5[1], sp5[2], label="α=0.4")
    plot!(sp6[1], sp6[2], label="α=0.9")
end
```




```
begin
    p3 = plot(sp4[1], sp4[2]./sp4[2], label="α=0.04", leg=:topright,
xlim=(290,400),
              title="O3 = 300DU", labelfontsize=8, xlabel="Wavelength [nm]",
                  ylabel="Ralative Ratio of spectral irradiance", )
    plot!(sp5[2]./sp4[2], label="α=0.4")
    plot!(sp6[2]./sp4[2], label="α=0.9")
end
```

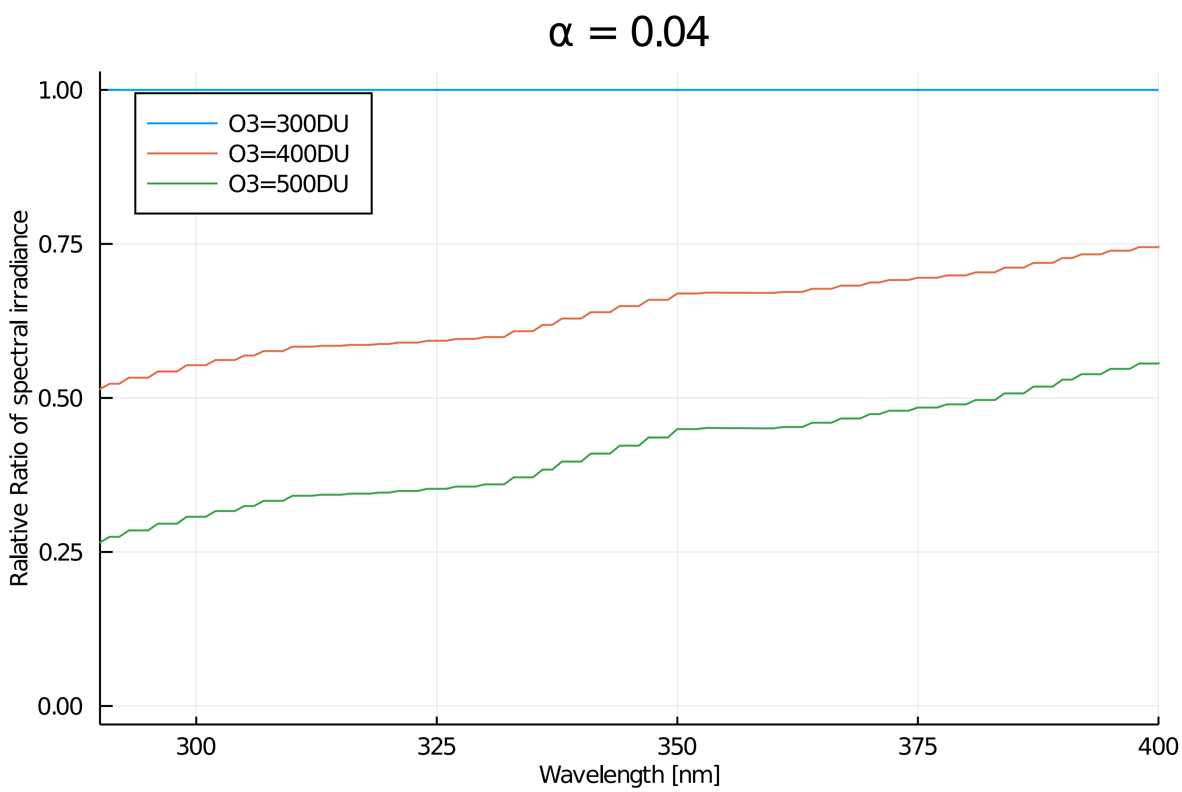
The spectral irradiance generally **increases with increasing albedo** given the same ozone concentration, the wavelength dependence is small;

The spectral irradiance also **decreases with increasing ozone concentration** given the same albedo, the relative ratio increases with increasing wavelength.




```
begin
    p2 = plot(sp4[1], sp4[2], label="O3=300DU", leg=:topleft, title="α = 0.04",
           xlabel="Wavelength [nm]", ylabel="Irradiance [W m⁻² nm⁻¹]",
labelfontsize=8)
    plot!(sp7[1], sp7[2], label="O3=400DU")
    plot!(sp8[1], sp8[2], label="O3=500DU")

end
```




```
begin
    p4 = plot(sp4[1], sp4[2]./sp4[2], label="O3=300DU", leg=:topleft,
              title="α = 0.04", labelfontsize=8, xlim=(290,400),
              xlabel="Wavelength [nm]",ylabel="Ralative Ratio of spectral
irradiance")
    plot!(sp7[2]./sp4[2], label="O3=400DU")
    plot!(sp8[2]./sp4[2], label="O3=500DU")
end
```