Radiation exercises - 1

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Background

In the following exercises we will explore the radiative properties of the Earth's atmosphere using the single column (SCM) version of the ECMWF IFS model.

The practical is divided in two parts. This first part deals with the radiative properties of atmospheric gases in a cloud-free atmosphere. The second part will focus on the radiative properties of clouds and their contribution to the energy budget.

From your `home` directory execute the following commands:

```
>cd metview
>cp -r /home/ectrain/trx/PA_TC_2019/RADIATION .
>cd RADIATION/Clear
>module swap metview/new
>metview
```

Clear sky: contribution of different gases to radiative transfer

In this practical, we will run the IFS SCM in clear sky conditions and we analyze the instantaneous radiative fluxes and heating rates.

1. We use a standard tropical atmospheric profile: the SCM input file `scm_in.clear.nc` contains as initial conditions the atmospheric profile from a location at a latitude of 25°N in June at 10 am local time. The surface albedo is 0.05, typical of a oceanic surface. The profiles of temperature and water vapour mixing ratio are shown by the black line in Fig. 2.

   (a) Open the namelist file `namelist_clear` and set up the SCM to run for a very short forecast (e.g. 10 hours) by changing the parameter `NSTOP` in the namelist `NAMCT0`. The parameter `NSTOP` in the namelist `NAMCT0` indicates the total number of time steps of the model run. The length of the time step is currently set at 900 s in the parameter `TSTEP` in the namelist `NAMDYN`. So for a 24-h forecast you would need `NSTOP=96` time steps.

   (b) Run the model using the running tool `ScmRun_clear` in MetView (set the output name to something like `out_control_clear.nc`. **Note:** do not use spaces in the filename).

   (c) To visualize the results, use the plotting macro `plot_clear_1D.mv` (right click on the icon, then click `execute`). When the small box appears, drag in it the output icon, edit the name of the output file and click `ok`. It will generate a PDF file with the profiles for the instantaneous heating rate and the upwelling, downwelling and net (= down – up) fluxes for the long-wave

(LW) spectrum and the short-wave (SW) spectrum. The profiles are for a single time step of the forecast, where both LW and SW fluxes are present. In this case it is close to local noon, 3 h (180 minutes) from the forecast start.

(d) Observe the SW and the LW heating rate profiles.

The SW shows heating over the whole profile, strong in the stratosphere above 15 km (model level 40).

Three major features are observed in the LW heating rate profile profile:

- negative heating (cooling) dominates in the troposphere
- small heating is observed in the lower-mid stratosphere above 100 hPa (model level $\sim$ 35)
- cooling dominates again in the upper stratosphere and mesosphere (above 50 hPa, model levels 0–30)

2. Now explore how the various trace gases contribute to the observed profile of radiative heting rate. By modifying the parameter `igas` in the `NAERAD` section of the namelist file `namelist_clear` you can control which gas is active in the radiation scheme. `igas=0` all gases active; `igas=1` only H_2O; `igas=2` only CO_2; `igas=3` only O_3. The contributions of the various trace gases to the total atmospheric transmissivity is shown in Fig. 1.

   Run the model for different `igas` values and save each output with a unique name (eg. `out_CO2.nc`).

   Produce the plots for each experiment using the plotting tool `plot_clear_1D.mv`. You can compare each output with the control profiles produced in point 1 above using the comparison tool `clear_compare`. Right click on the icon, `edit` and just drop the output from the runs you want to compare in the two boxes `Scm Data` and `Scm Comparison Data`, adjust the `Scm Data Title` and `Scm Comparison Data Title` and set the name of the output file in the last box of the user interface `Scm Output File Path` (use unique names for each comparison, e.g. `h2o_vs_cntl`).

   Compare the results with those analyzed in point 1d):

   - where do you see the impact of H_2O, CO_2 and O_3 in the LW profiles?
   - where do you see the impact of H_2O, CO_2 and O_3 in the SW profiles?
   - why does O_3 cause a warming in the mid stratosphere ($\sim$50 hPa) in the LW?
   - why does CO_2 cause a warming around the tropopause level ($\sim$100 hPa) in the LW? (HINT: look at the temperature profile for the standard tropical profile in Fig. 2)

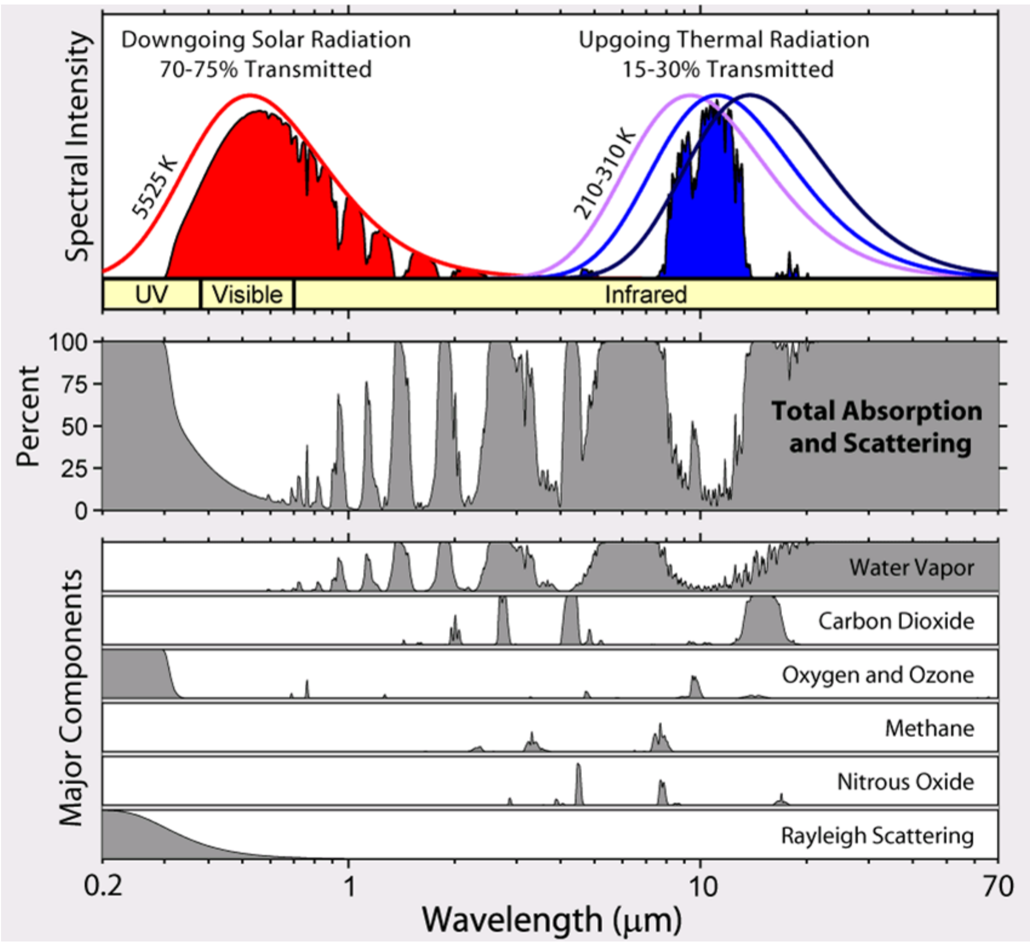

Figure 1: Total extinction in clear sky and major contributions from the trace gases. Single gases can be activated in the radiation scheme by changing the parameter `igas` *in the namelist file* `namelist_clear`. `igas=0` *all gases active;* `igas=1` *only H_2O;* `igas=2` *only CO_2;* `igas=3` *only O_3.*

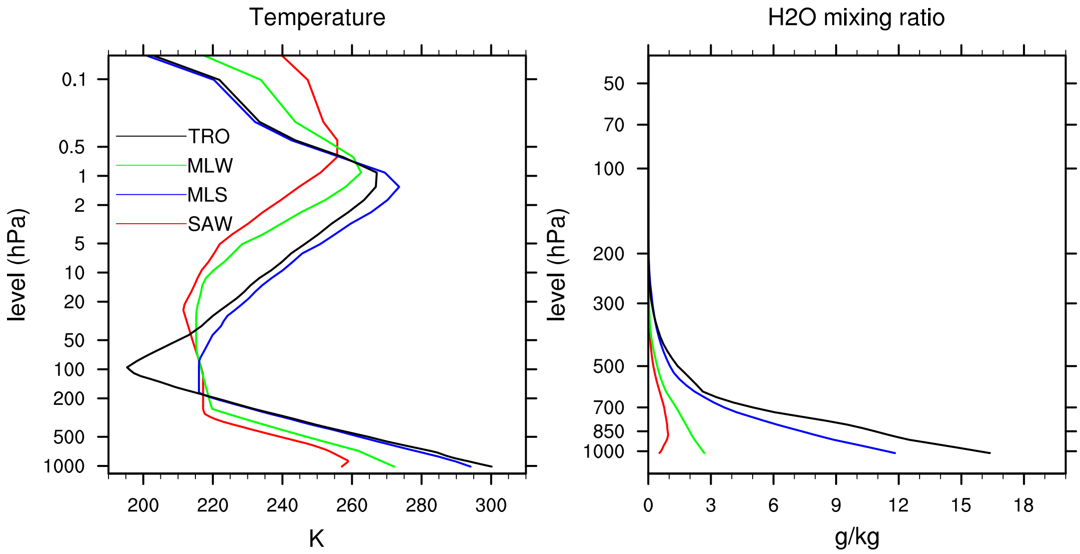

Figure 2: Vertical profiles of temperature and water vapor mixing ratio for four standard atmospheres (TRO=Tropical, MLW=Mid Latitude Winter, MLS=Mid Latitude Summer, SAW=Sub Arctic Winter).