Updated radiative transfer modelling to simulate the Pressure Modulated Radiometer (PMR)

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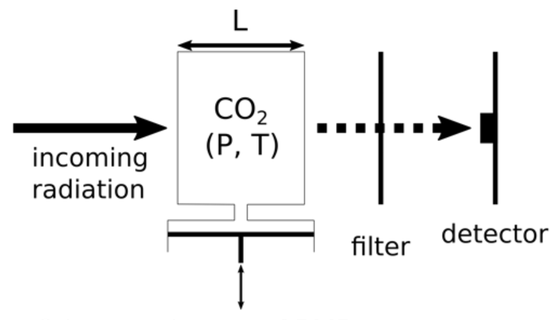
PMR instrument

As part of the EU-funded Copernicus Climate Change Service (C3S) program, we contribute to the rescue, assessment and preparation of observations from several satellites that flew in the 1970s for the next re-analysis ERA-6.

The Pressure Modulator Radiometer (PMR) was an instrument carried onboard Nimbus 6 [2].

Measurement principles

The purpose of this instrument is to measure the atmosphere's temperature distribution in the upper stratosphere and mesosphere by using the pressure modulation of a CO_2 cell placed in the optical path.



Schematic diagram of PMR measurement.

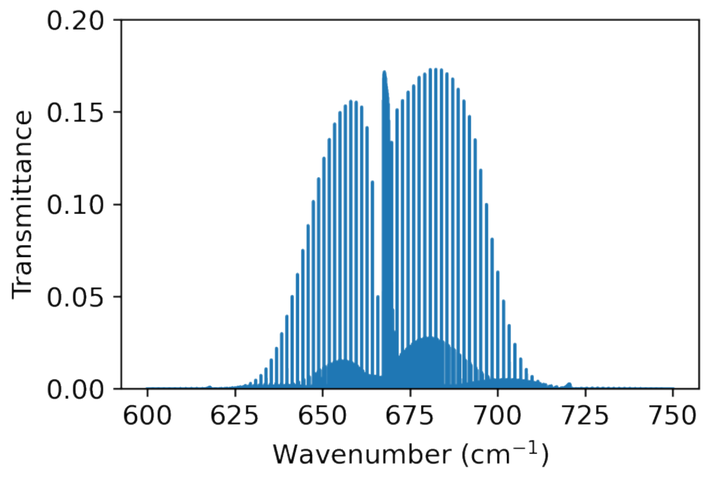
The pressure in the cells varies sinusoidally:

$$P = P_{mean} + \Delta P_c \ sin(\omega t).$$

Spectral Response Function

To simulate the response of the PMR, we take into consideration the pressure cycle and the wide blocker filter. The pressure modulation cycle within the gas absorption cell can be modeled using a two-cell approximation [1]:

$$H_\nu = t_\nu^{Pmin} - t_\nu^{Pmax}.$$



Spectral Response Function for cell 1 of the PMR

Probe the middle atmosphere

Weighting Functions

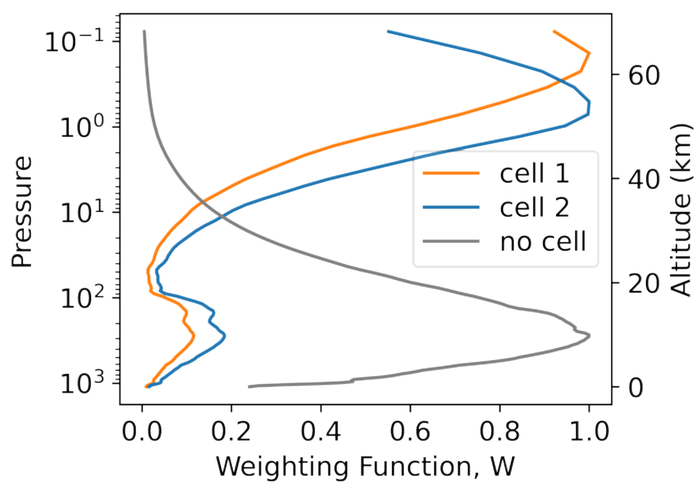
We analyse the weighting function, W, to determine the layer of the atmosphere at wich PMR is sensitive. At each level of the atmosphere, we calculate the convoluted transmittance with:

$$\tau_{ch} = \frac{\int \tau_\nu G_\nu H_\nu d\nu}{\int G_\nu H_\nu d\nu},$$

where H_ν, is the SRF of the cell and G_ν the SRF of the wideband filter.

To obtain the weighting function, we differentiate the convoluted transmittance of each level with respect to the pressure, P, at the corresponding level such as:

$$W(P) = \frac{d\tau_{ch}}{dln(P)}.$$



Weighting Functions of the PMR cells and PMR wideband on the standard profil 83 of the ECMWF

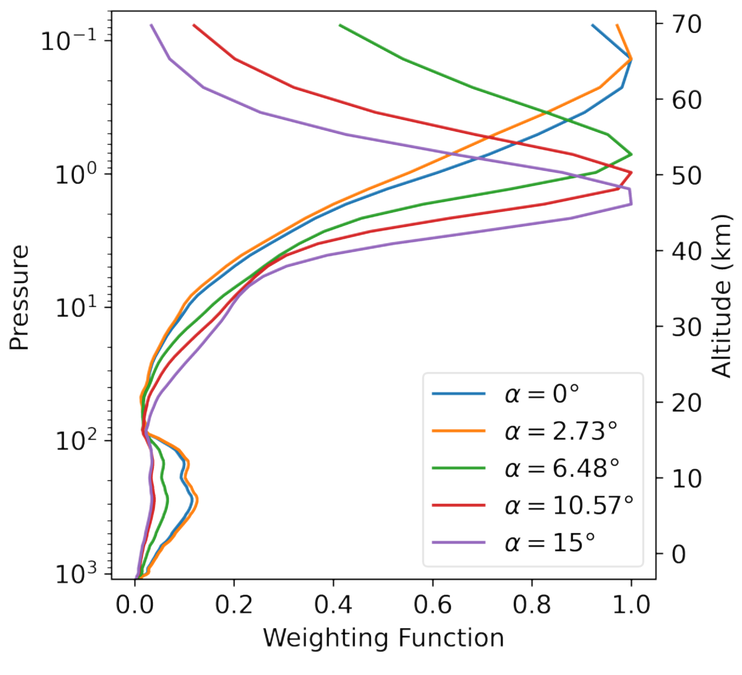
The principle of pressure modulation allows to probe the atmosphere at differents altitudes.

Doppler scanning

PMR instrument can alter its viewing angle from nadir to $\pm$ 15° along track, introducing Doppler shifts:

$$\nu = \nu_e \left(1 + \frac{v \sin(\alpha)}{c}\right).$$

Where ν_e is the frequency of the line as emitted or absorbed by the atmospheric gas, and c is the speed of light, and ν is the frequency observed by PMR.

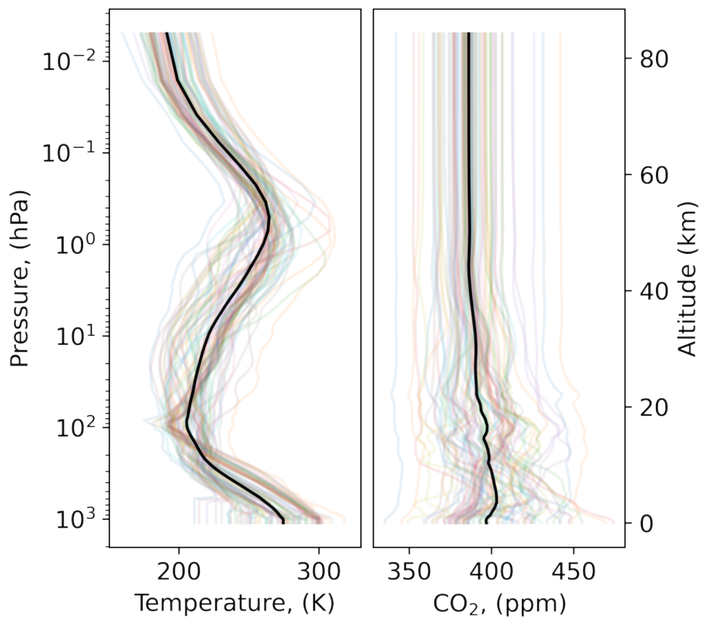


Weighting Functions of the PMR cell 1 on profil 83 for differents angle of view

The greater the angle is, the lower the weighting function peaks.

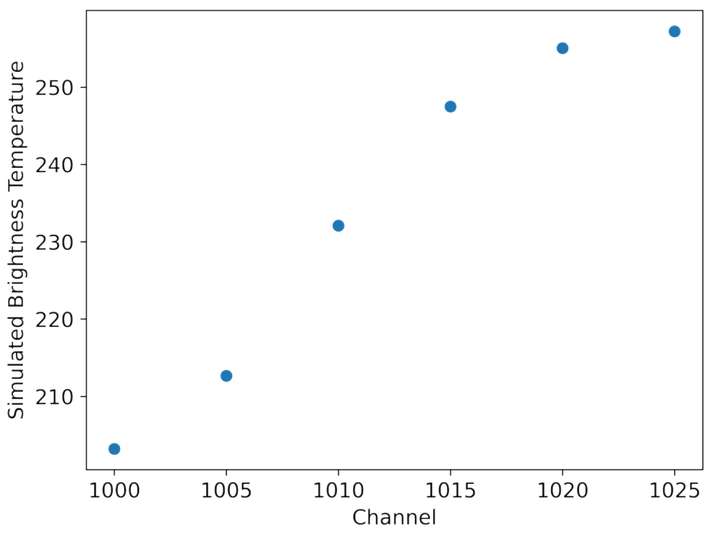
Atmospheric profiles

To train the RTTOV atmospheric transmittance parametric model, we use a set of 83 atmospheric profiles.



Atmospheric profiles used to compute the RTTOV model.

The CO_2 concentration in the current set of profiles does not match CO_2 abundance of the 1970s. The channel-dependent increase in simulated brightness temperature corresponds to the temperature in the mesosphere where the weighting function peaks.



Simulated brightness temperature with RTTOV, channel 1015 refers to the cell 1 at its pressure setting 0 and a scan angle sine of 15 °.

Conclusion

- We use LBLRTM to simulate PMR cells
- PMR instrument probes the upper stratosphere
- Doppler scanning must be taken into account

Further investigations :

- Adjust atmospheric profiles (altitude, CO_2 concentration, etc)
- Compare with observations (ongoing)

[1] H. Brindley, A. Geer, and J. Harries. Climate variability and trends in ssu radiances: A comparison of model predictions and satellite observations in the middle stratosphere. *Journal of climate*, 1999.

[2] P. Curtis, J. T. Houghton, G. Peskett, and C. Rodgers. Remote sounding of atmospheric temperature from satellites v. the pressure modulator radiometer for nimbus f. *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences*, 1974.