Implementation of far infrared gaseous absorption/emission in Radiative Transfer Code MOMO

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1. **MOMO**: Matrix-Operator Model

- Transmission/absorption, scattering in SW (200-3650nm)
- The same + Emission in LW (3.65–100µm)
- Remote sensing (inversion of sat data) or simulations of atmospheric RT, for gaseous atmospheres, aerosols, clouds
- Radiative budget (forcings, heating rates), atmospheric chemistry (actinic fluxes)
- Ocean remote sensing

- The code is tested in SW (200-3650nm)
- The code is developed in MI (3.65–15µm) and tests will be soon published
- The code is currently developed in FI (15–100µm)

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1 Fell F. and J. Fischer, JQSRT, 2001
1. \textit{MOMO}: Matrix-Operator Model

- Functioning scheme:
  \textbf{INPUT}: vertical profile $T(z)$, $P(z)$, $c(z)$
  \textbf{OUTPUT}: Fluxes at each wanted level (spectral radiances or irradiances)

- \textit{CGASA}: Computes gas extinction coeff
- \textit{KBIN}: Makes a k-distribution (reduce comp. time), ideal for sat
- \textit{SCA}: Computes phase functions and macro param of scatterers
- \textit{MOMO}: Solve the radiative transfer equation with all the datas
1. Application of MOMO to far Infrared

- Whole atmosphere Transmission spectrums, vertical transmission profiles, TOA upward radiances, Ground downward radiances, Heating rate vertical profile

- Gaseous Species:
  - Mixed Gases \((CO_2, N_2, O_2, N_2O, CO, CH_4, NO)\)
  - \(H_2O\)
  - \(O_3\) (stratosphere)

- Parameters: \(T(z), P(z),\) gas concentrations: MS Profile, 27 layers.
1./ Application of MOMO to far Infrared

3 Zones: 10-15 microns ($N_2O+CO_2$), 20-35 microns ($N_2$) and 35-100 ($N_2+O_2$))
The total transmission is quasi 0! We have to look the transmission profile.
1./ Vertical profile of transmission

For $\lambda = 27.3\mu m$: TOA remote sensing sounds the middle/top of troposphere
1. Vertical profile of transmission

For $\lambda=28\mu m$: TOA remote sensing sounds upper the boundary layer limit
We can see which part of the spectrum sounds which height of the atmosphere.
Ground radiance measurements sound the narrowest layers.
1. Far-Infrared Heating-Rates

Far-IR Heating-Rates is 15% of the Middle-IR Heating-Rates

\[ HR = \frac{\delta T}{\delta t} = -\frac{g}{C_p} \frac{\delta F}{\delta P} \]
2. CGASA: Modeling the gas absorption

- **CGASA:**
  - Takes line parameters of *HITRAN2008*
  - Takes continuum parameters of recent models (*CKD, MT-CKD*)
  - For the wanted spectral intervals, looks all the lines in the neighborhood and compute the optical depth
  - Cut the far wings and the basement, put a form factor: $F_{\text{fac}}$
  - Is tested with *LBLRTM* in UV, Vis and MI (0.2-15μm)

\[ F_{\text{fac}} = 1 - \frac{\nu^2_{\text{lim}}}{\nu^2_{\text{lim}} - \Delta \nu^2} \]
3. CGASA vs LBL-RTM: gas transmission

Zoom on the Optical Depth for 15-20\( \mu \)m. Differences on the peaks only.
Zoom on the Optical Depth for 20-35µm. Differences on the peaks only

After 20 microns, continuum of LBLRTM is taken
3. CGASA vs LBL-RTM Optical Depth

Differences are quite big…. Due to the resolution!

- h2o, cgasa
- h2o, lblrtm
We compute the OD with a higher resolution (0.1nm) on the band 25-30µm
Differences are much smaller: divided by more than 10.
3. CGASA vs LBL-RTM, rad(TOA)

TOA Radiance with crude resolution: There are some differences but not so obvious
3. CGASA vs LBL-RTM, rad(TOA)

\[ \Delta(\text{rad}) = 100 \times \frac{\text{rad}_{\text{CGASA}} - \text{rad}_{\text{LBLRTM}}}{\text{rad}_{\text{CGASA}}}, \text{ in } \% \]

... but many over 5-10%
With 0.1 nm resolution, the differences disappear.
... and most of the points are under 0.2%, quasi all are under 1%
3. CGASA vs LBL-RTM: conclusion

- Resolution is a crucial issue (0.1 nm = good standard)
  -> If, then need to economize time => K-distribution
- Input continuum values, efficiency for CO₂ and O₃
- Improve lines modeling: form factor, etc...

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\begin{tabular}{l}
\hline
\text{wavelength, nm} & \text{optical depth} \\
899.5 & 10^0 \\
900.0 & 10^{-1} \\
900.5 & 10^{-2} \\
901.0 & 10^{-3} \\
\hline
\end{tabular}
```

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\begin{tabular}{l}
\hline
\text{wavenumber, cm}^{-1} & \\
11116 & 10^0 \\
11114 & 10^1 \\
11112 & 10^2 \\
11110 & 10^3 \\
\hline
\end{tabular}
```
4./ Continuum sensibility

- We take LBL-RTM input data, and look:
  - With normal continuous ($cont=1$)
  - Without continuum ($cont=0$)
  - With half continuum ($cont=0.5$)
  - With double continuum ($cont=2$)

- We look what happens on:
  - Transmission
  - Optical Depth
  - TOA radiance
  - Heating rates
4./ Continuum sensibility: on transmission

Transmission is of course impacted by the continuum value
4./ Continuum sensibility: on transmission

Transmission of mixed gases only is much more significant
The more continuum we have, the less TOA radiance we have.
4. Continuum sensibility: on $\text{Rad(TOA)}$

$\Delta(\text{rad}) = 100 \times \frac{\text{rad}_{\text{CGASA}} - \text{rad}_{\text{LBLRTM}}}{\text{rad}_{\text{CGASA}}}$, in %

TOA fluxes: 6% more without cont, 2.5% more with half, 2.5% less with double
More continuum decrease the HR in the boundary layer and increase HR over it.
CONCLUSIONS:

- **MOMO** = good tool to simulate the fluxes also in Far-IR: TOA fluxes, heating-rates.
- **MOMO** = good tool for sensitivity study
- **CGASA** (spectroscopic subprogram of **MOMO**) is true, but caution to the resolution, problem of efficiency, theoretical interrogations on line shape factor.

OUTLOOK:

- We need to put our coefficients for continuum over 20µm
- We need to find a faster method for **CO₂** and **O₃**
- We need to compute the ext coeff with a high resolution and then use the k-distribution method for the fluxes computing

THANK YOU FOR YOUR ATTENTION!