A fast approach to compute atmospheric radiative transfer in non-scattering medium

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Context
- Studying impact of the climate on EDF facilities and reciprocally: problem of cloudy atmosphere for photovoltaic energy production
- Having a local-scale forecast model able to simulate fog formation and evolution
- Taking account spatial heterogeneities with a 3-D Radiative Transfer model

Objectives
- Using a 3-D resolution method, fast as possible and accurate enough
- Coupling emissivity functions with Discrete Ordinates Method
- Comparisons of heating rates and fluxes computed by the existing and validated 1-D model in atmospheric module of Code_Saturne®
- Comparisons with a radiative transfer model which uses multi-spectral resolution (Correlated-K Distribution)

Theoretical approach - Plane-Parallel Atmosphere

Radiative Transfer Equation on fluxes
\[
\frac{\partial F^\uparrow(z)}{\partial z} = \frac{3}{5} k(z) [F^\uparrow(z) - \sigma T^4(z)] \\
\frac{\partial F^\downarrow(z)}{\partial z} = \frac{3}{5} k(z) [F^\downarrow(z) - \sigma T^4(z)] \\
F^\uparrow(z) = \sigma T^4(z) F^\downarrow(z) + \epsilon(z, z_0) \sigma T^4(z)
\]

Radiative Transfer Equation on radiance
\[
\frac{\partial I}{\partial z}(z, \cos \theta) = -k(z) [I(z, \cos \theta) + I^0(z)]
\]

Solution for the Cooling to Space approximation
\[
\epsilon(z, z') = \frac{1}{\sigma T^4} \int_0^{\infty} [1 - T(z',\cos \theta)] \pi k(z') \, d\lambda
\]

Heating/Cooling rates comparisons - Clear sky conditions - Validation

Cloudy Atmosphere

ParisFOG field experiment - 12h

Conclusion/Further work
- New approach fast and accurate enough validated on semi-analytical solutions
- Infrared heating/cooling rates in clear sky or cloudy condition: strong cooling above the fog layer, heating below it
- Weak/Strong coupling of our approach with Fluid Dynamics

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