Revitalization of gaseous transmission functions in ACRANEB radiation scheme using RRTM as database

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Motivation

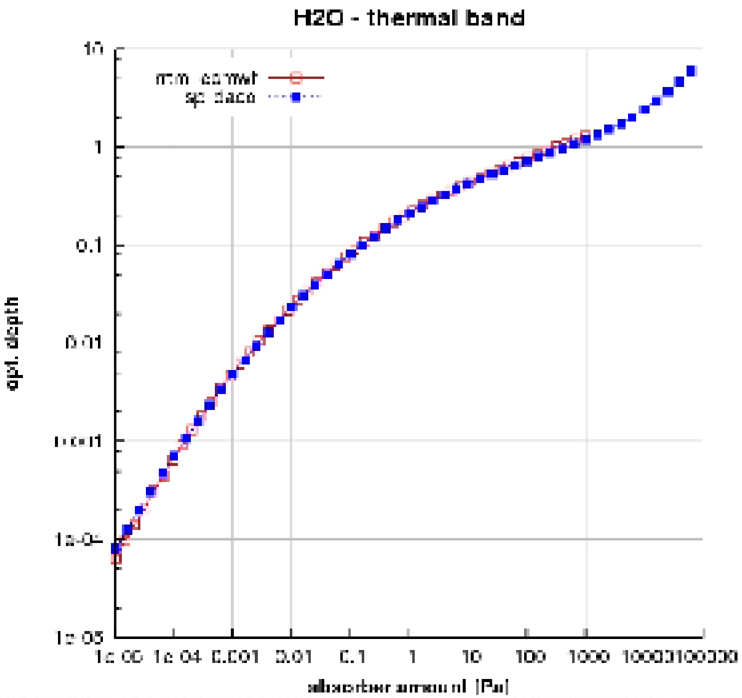
- deficit of current ACRANEB scheme in terms of overestimation of cooling rates in the lower troposphere
- one can start verifying transmission function fits on the first place
  (18 years old stuff with not much documentation)

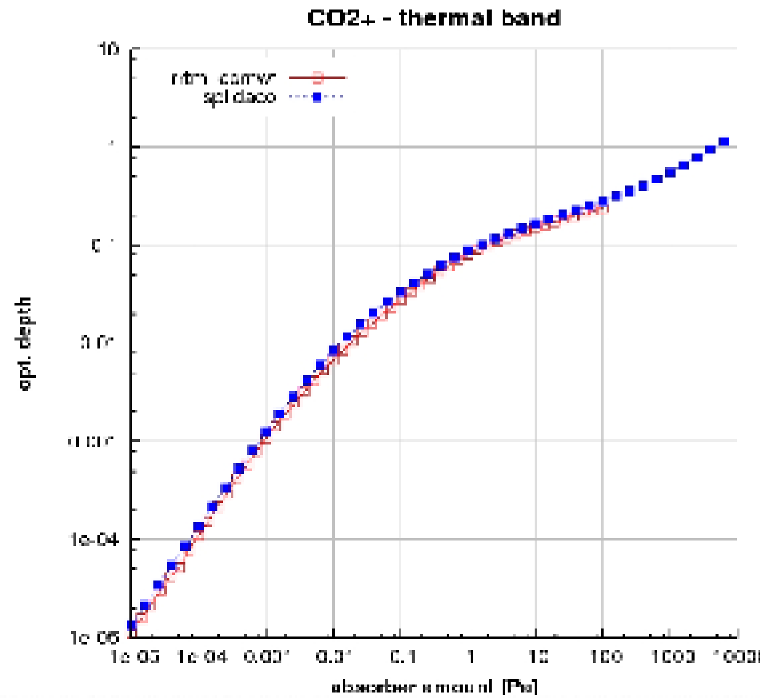
Strategy

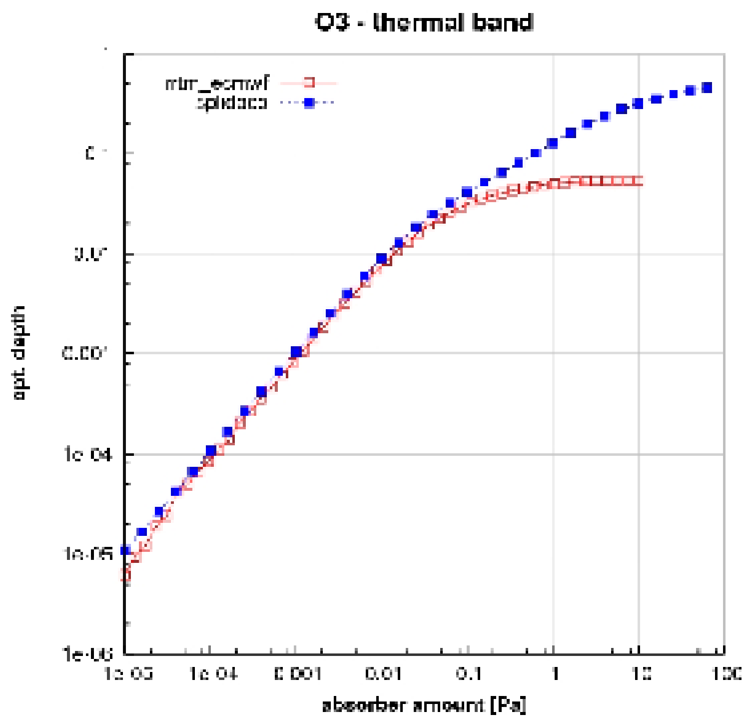
- extraction of gaseous transmissions from RRTM (Rapid Radiative Transfer Model) – to be used as a new dataset for fitting
- revision of the fitting procedure and verifying of the reproducibility of the old fits
- checking the impact of the new TF (transmission function) fits
- verifying other simplifying assumptions

Dataset preparation

- one uses high precision (but rather expensive) band models to compute ‘exact’ gaseous transmissions as functions of absorber amount, T and p
- SPLIDACO – band model used to create a dataset for fitting the original TFs
- RRTM – band model based on LBLRTM, adopted to extract a new gaseous transmissions’ dataset


H2O - thermal band
mtm_ecmwf
spl daco
opt. depth
absorber amount [Pa]


CO2+ - thermal band
mtm_ecmwf
spl daco
opt. depth
absorber amount [Pa]


O3 - thermal band
mtm_ecmwf
spldaco
opt. depth
absorber amount [Pa]

Fitting method

- using Malkmus band model for evaluation of equivalent width $\boldsymbol{W}$

$$W = \frac{2a}{b}\frac{q_r}{q_n}\left[\sqrt{1+4b\frac{q_n^2}{q_r}}-1\right]+cq_r$$

$\boldsymbol{a}$ – weak line parameter

$\boldsymbol{b}$ – strong line parameter

$\boldsymbol{c}$ – continuum parameter

$\boldsymbol{q_r}, \boldsymbol{q_n}$ - reduced (by T and p factors) and unreduced absorber amounts

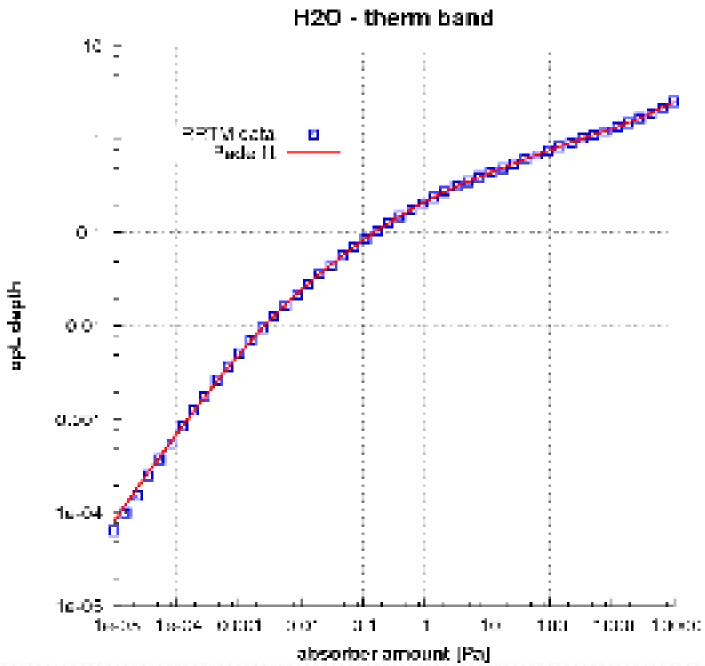
Fitting method

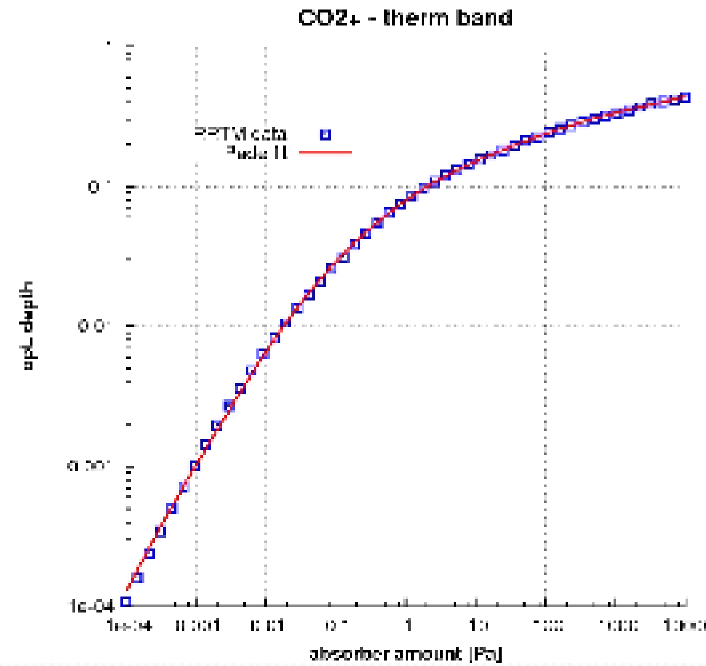
- due to non-linear dependence, optical depth $\boldsymbol{\delta}$ is expressed as a function of $\boldsymbol{w}$ in a form of Pade approximant

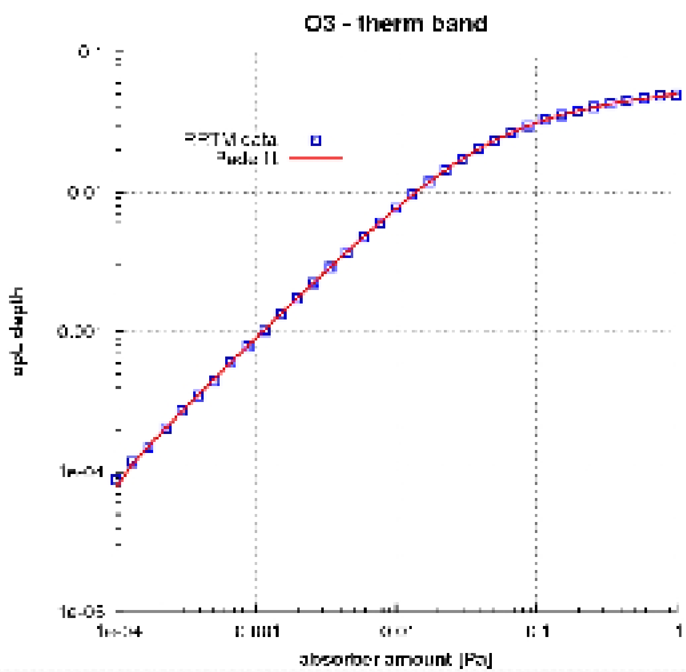
$$d_g = \frac{P(w)}{Q(w)} = w \frac{1 + \text{¥} p_n w^n}{1 + \text{¥} q_m w^m}$$

- where $\boldsymbol{w} = \boldsymbol{W}/\boldsymbol{\delta}'$ ($\boldsymbol{\delta}'$ … mean interdistance of abs. lines)

- one has to simply find optimal coefficients **a, b, c** and $\mathbf{p}_n$, $\mathbf{q}_m$


H2O - therm band
RRTM data
Pade fit
opt. depth
absorber amount [Pa]


CO2+ - therm band
RRTM data
Pade fit
opt. depth
absorber amount [Pa]


O3 - therm band
RRTM data
Pade fit
opt. depth
absorber amount [Pa]

Fitting method

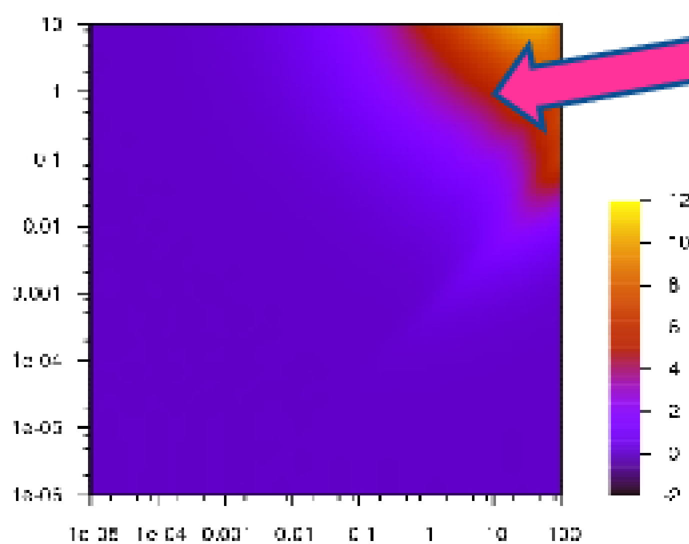
- we managed to revitalize the TF fits using RRTM data
- this is nice but actually doesn’t help much
- time to check some simplifying assumptions!

Assumption for composite of gases

- total optical depth of the gas composite is equivalent to the sum of individual gaseous optical depths

$$\delta_{tot} = \delta_1 + \delta_2 + \delta_3$$

relative error for H2O + CO2 composite



NOT valid for higher absorber amounts

Correction for composite of gases

- proposed solution:

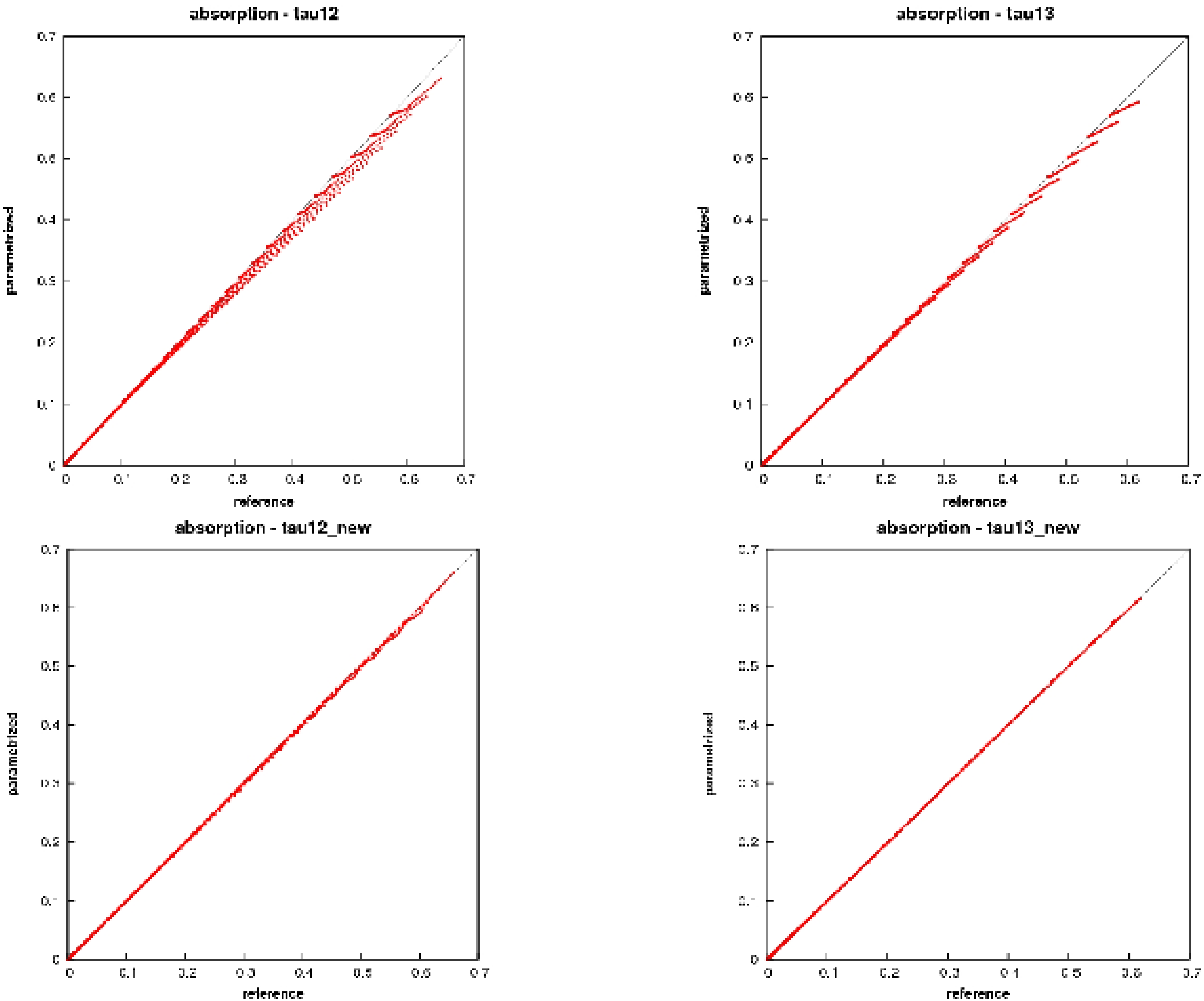
$$\boldsymbol{\delta}_{tot} = \boldsymbol{\delta}_1 + \boldsymbol{\delta}_2 + \boldsymbol{\delta}_3 + X_{12} + X_{13} + X_{23} + \ldots \text{ (?)}$$

current solution | new correction terms

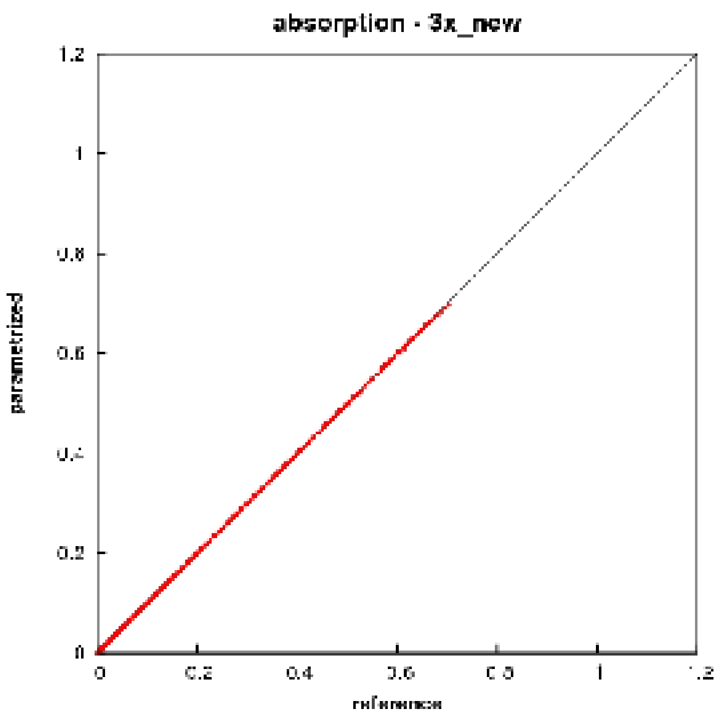
$X_{ij} = \boldsymbol{\delta}_{ij} - (\boldsymbol{\delta}_i + \boldsymbol{\delta}_j)$ … 'double-composite' correction

$$X_{ij} = \sqrt{e \frac{u_i}{(u_i + f)} \frac{u_j}{(u_j + g)}}$$

$\boldsymbol{u}$ – *absorber amount*
$\boldsymbol{e, f, g}$ – fitting coeffs

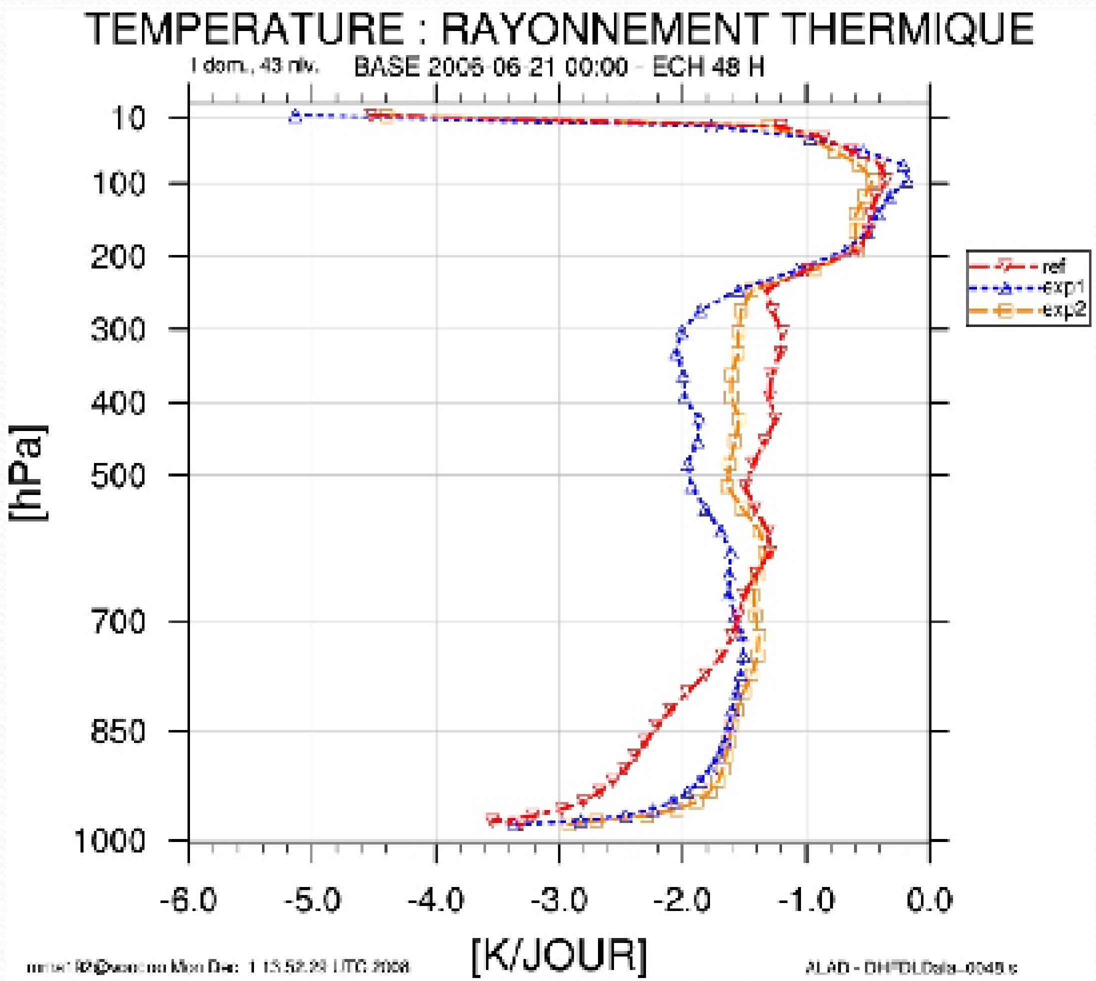

absorption - tau12
absorption - tau13
absorption - tau12_new
absorption - tau13_new
parametrized
reference

Correction for composite of gases



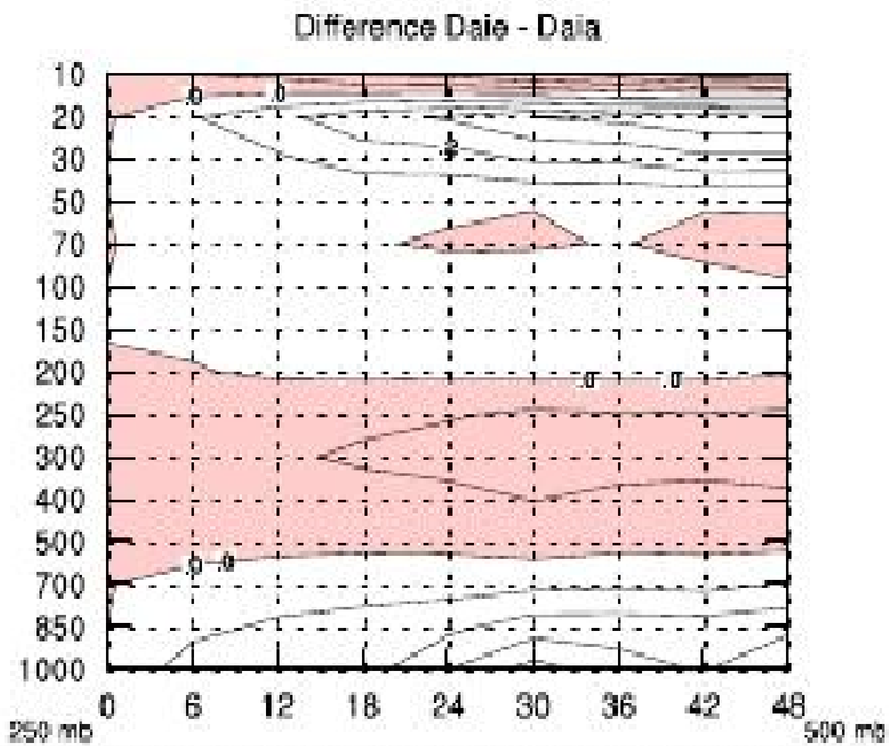
- absorption of composite of all three gases after applying corrections X_{12}, X_{13}, X_{23}
- additional higher order correction term X_{123} not necessary, fortunately

DDH Inter-comparison

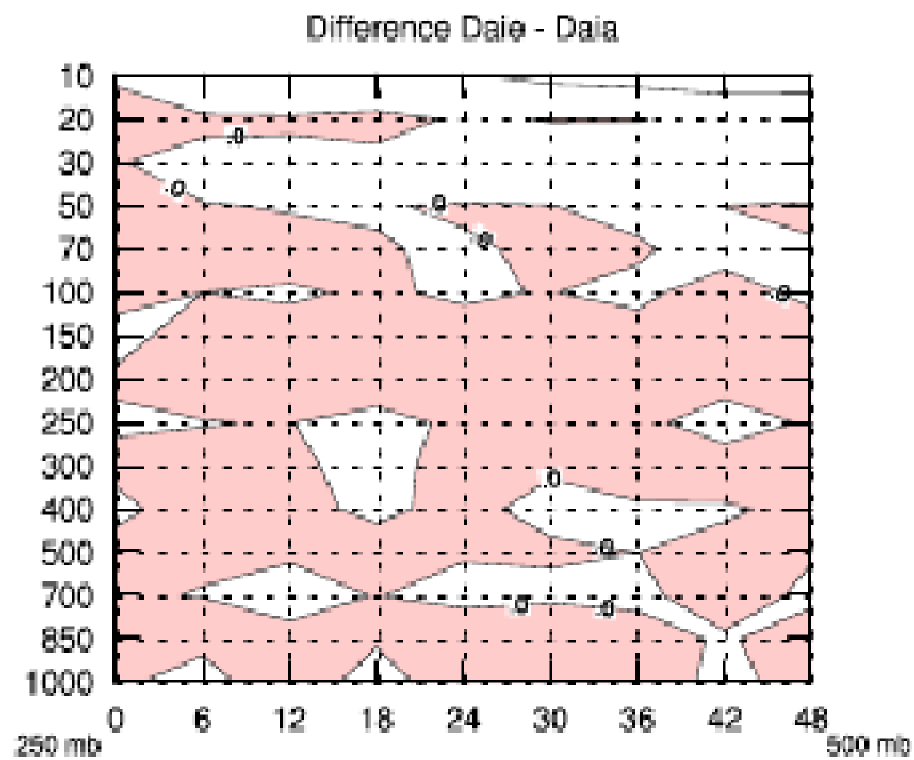


Verification

Period 20080501…20080510



bias



STDE

Conclusion

- we obtained cooling rates which are now closer to the ones in RRTM (especially in lower troposphere)
- we achieved this with minimal extra computational cost (only one additional square-root evaluation)
- however, we get too big positive bias – most probably the consequence of the compensating errors in the previous setup
- we need to readjust tuning of other physical parametrizations to find a new consistent setup

Further plans

- introduce ‘overlapping’ correction for solar part
- introduce climatology for aerosols’ optical properties
- development of time intermittent scheme:
  - principle of constant gaseous opt. depths within N integration time steps
  - clear-sky fluxes at the beginning of each updating period are exact
  - interaction with clouds can be recomputed in every time step (without excessive CPU burden)

Thank you!