# Statistical method for the weighting function in the thermal radiation

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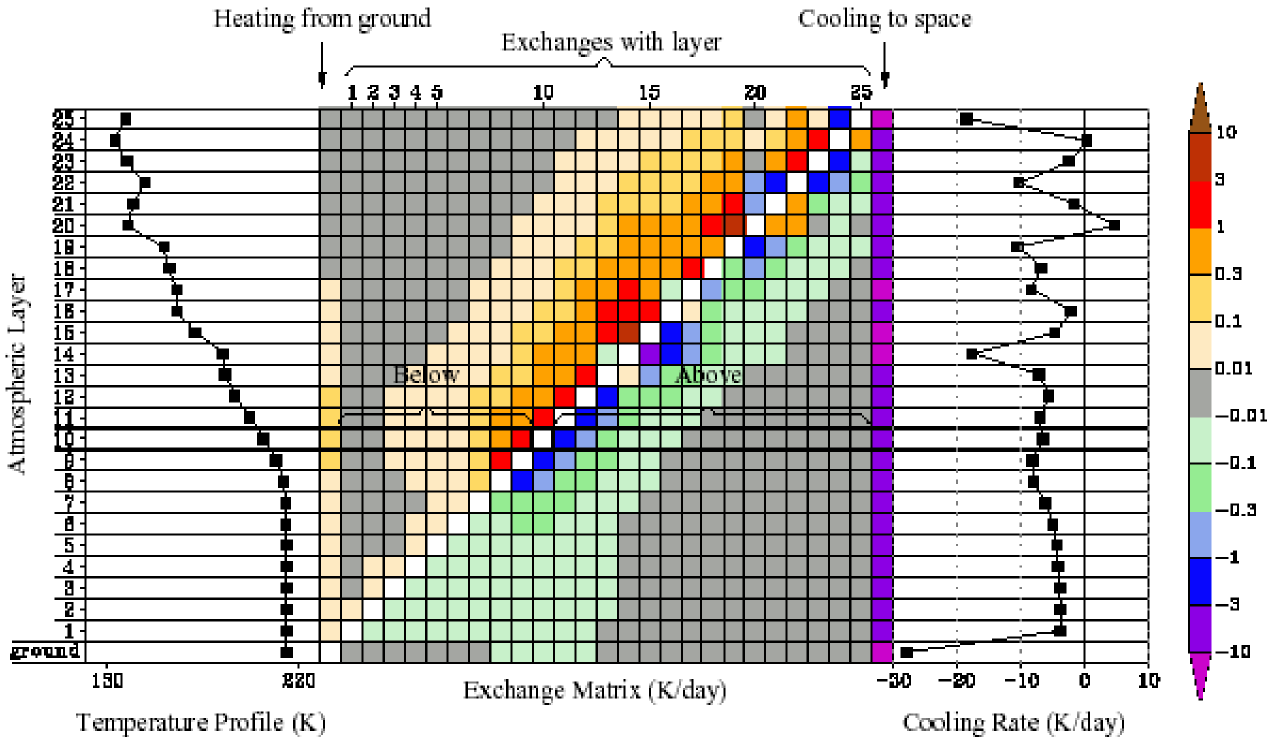
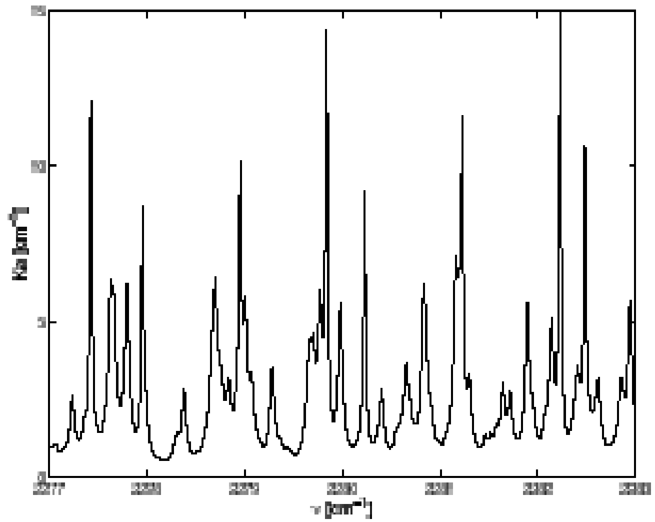
# Radiative transfer scheme

- δ-two stream approximation of radiative transfer equation for solar and thermal bands
- Adding method (solving linear system of equations)
- Economical computation (a good quality cost ratio)
- Separation of cloud and gaseous effects

# Thermal radiative fluxes

- Improvements on the basis of Net Exchanged Rate (NER) formalism
- Better estimation of optical thickness of gaseous absorption for every layer in a simplified geometry and re-inject them into computation together with grey body effects


Heating from ground
Exchanges with layer
Cooling to space
Atmospheric Layer
Below
Above
ground
Temperature Profile (K)
Exchange Matrix (K/day)
Cooling Rate (K/day)



# NER

- The atmosphere is divided in homogeneous layers
- Thermal exchange terms
  - Primary
    - Cooling to space (CTS)
    - Exchange with surface (EWS)
    - Exchange with adjacent layers (EAL)
  - Secondary
    - Exchange with other layers

# NER

- The atmosphere is divided in homogeneous layers
- Thermal exchange terms
  - Primary - *as accurate as possible*
    - Cooling to space (CTS)
    - Exchange with surface (EWS)
    - Exchange with adjacent layers (EAL)
  - Secondary - *approximate treatment*
    - Exchange with other layers

# Algorithm

- a calculation [I] with profile A and $\delta\tau_{gas}$(CTS)
- a calculation [II] with profile B and $\delta\tau_{gas}$(EWS)
- 3 calculations [III,IV,V] with profiles A,B,C and $\delta\tau_{gas}(EBL)=\delta\tau_{min}$

Result is obtained:

[I] + [II] - [III] - [IV] + [V])

(multiplying by $\Pi$B exept [V] and [VIII])

# Algorithm – vertical temperature profile

- Profile A:
  $\Pi B = 1$ at the ground and everywhere in the atmosphere => allows to suppress all other exchanges than ‘cooling to space’ (CTS)
- Profile B
  $\Pi B = 1$ at the ground and $\Pi B = 0$ everywhere in the atmosphere => allows to suppress all other exchanges than ‘exchange with surface’ (EWS)
- Profile C
  The one corresponding to the physical truth => it mixes CTS, EWS with the ‘exchanges between layers’ (EBL)

# Algorithm

- a calculation [I] with profile A and $\delta\tau_{gas}$(CTS)
- a calculation [II] with profile B and $\delta\tau_{gas}$(EWS)
- 3 calculations [III,IV,V] with profiles A,B,C and $\delta\tau_{gas}(EBL)=\delta\tau_{min}$

- 3 calculations [VI,VII,VIII] with profiles A,B,C and $\delta\tau_{gas}(EBL)=\delta\tau_{max}=\delta\tau_{prox}$

More accurate result is obtained:

$[I] + [II] – \alpha.([III]+[IV]-[V]) - (1-\alpha).([VI]+[VII]-[VIII]) + \gamma$

(multiplying by ΠB except [V] and [VIII])

# Method

$[I] + [II] - \alpha\ ([III]+[IV]-[V]) - (1-\alpha)\ ([VI]+[VII]-[VIII]) + \gamma$

How to calibrate $\alpha$ and $\gamma$?

$\gamma = 0$ in the statistical model; this implies

$0 <= \alpha <= 1$ (0 corresponds to $\delta\tau_{min}$ ; 1 to $\delta\tau_{max}$)

# Method

- vertical profiles over globe (ARPEGE)
- for gas only atmosphere (clear sky)
- computation of EBL fluxes* using $\delta\tau_{min}$ , $\delta\tau_{max}$ and exact computation

* Two possibilities EAL accurate or inside statistical fitting

# Method

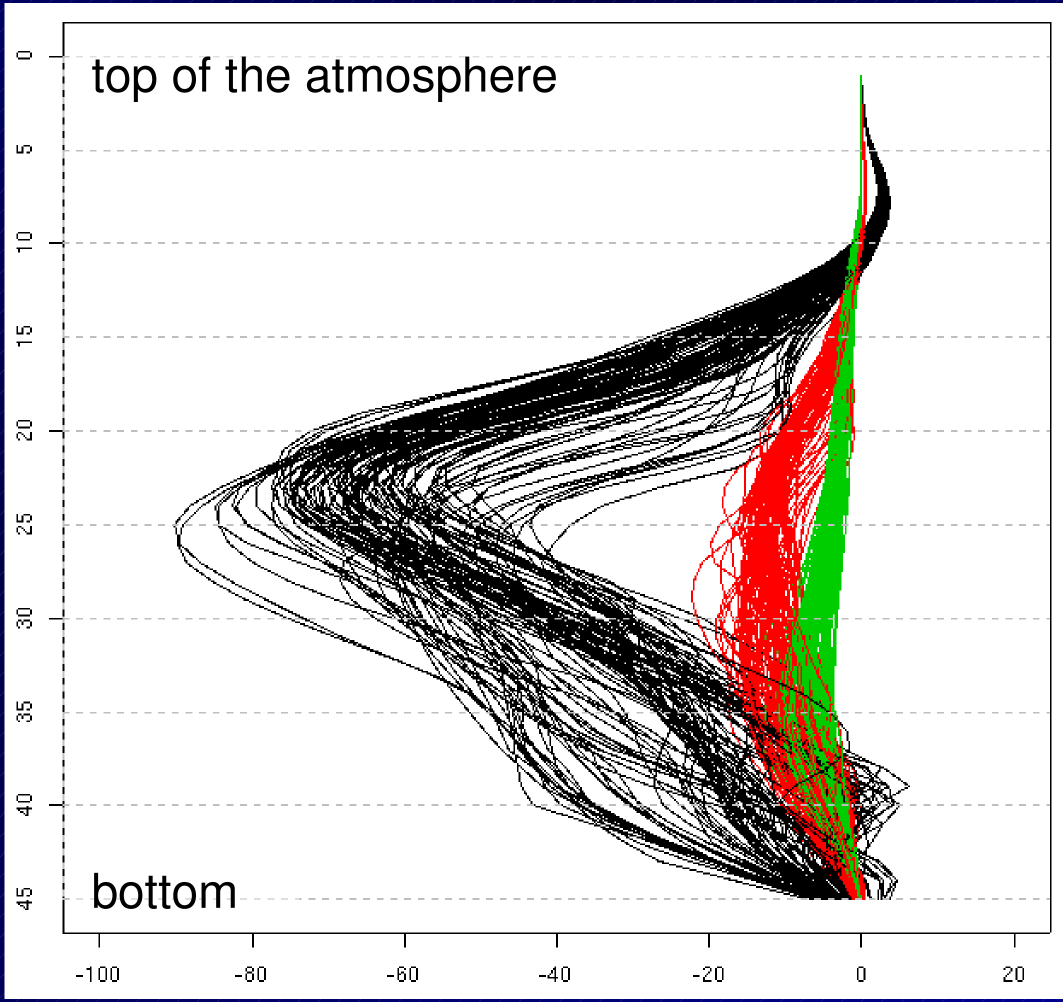
EBL fluxes using

$\delta\tau_{min}$ - green

$\delta\tau_{max}$ – black

$\delta\tau$ - red

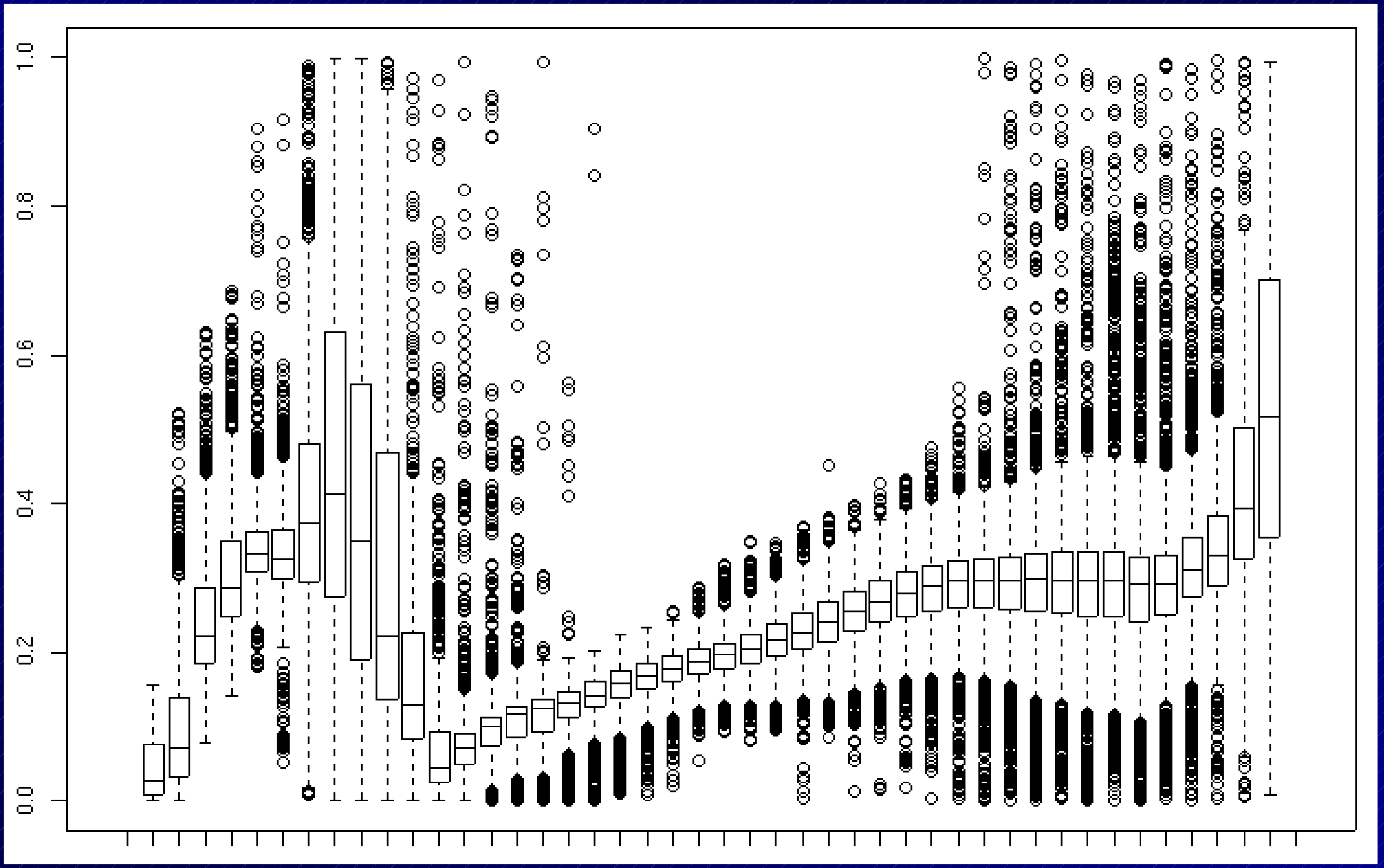
for some vertical profiles



# Method

## Computation of α

α




top model levels bottom

# Method

α increases:

in the lower atmosphere

in regions with temperature inversions

$$\alpha = N\left(\frac{p}{p_s}\right) + K\left(\frac{\partial c_p \Theta}{\partial \varphi}\right)$$

# Method

1. version:

$$\alpha = 0.3\frac{p}{p_s} + 0.1\left(\frac{\partial c_p \Theta}{\partial \varphi}\right)$$

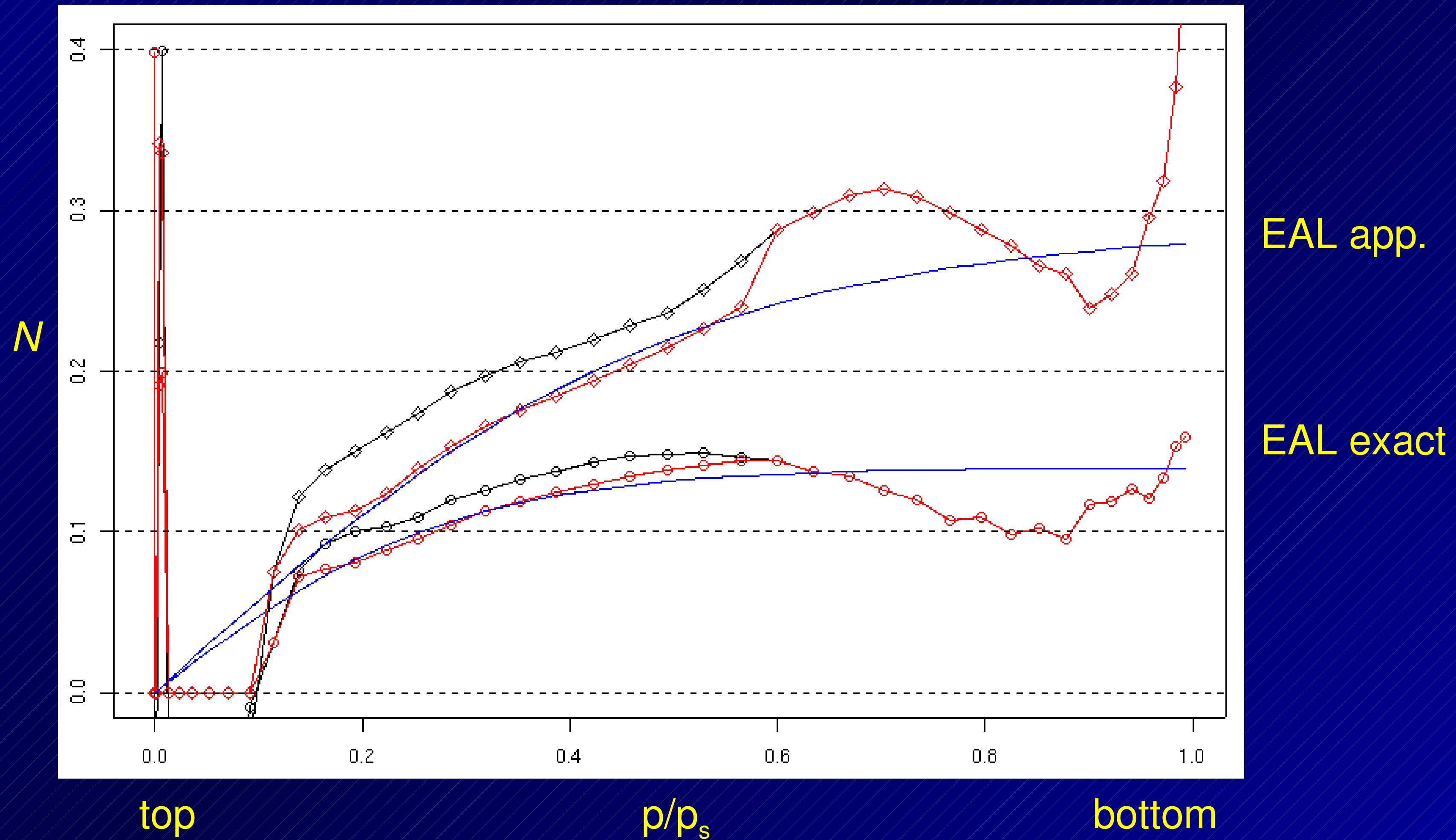
no vertical dependency for stability part

2. version:

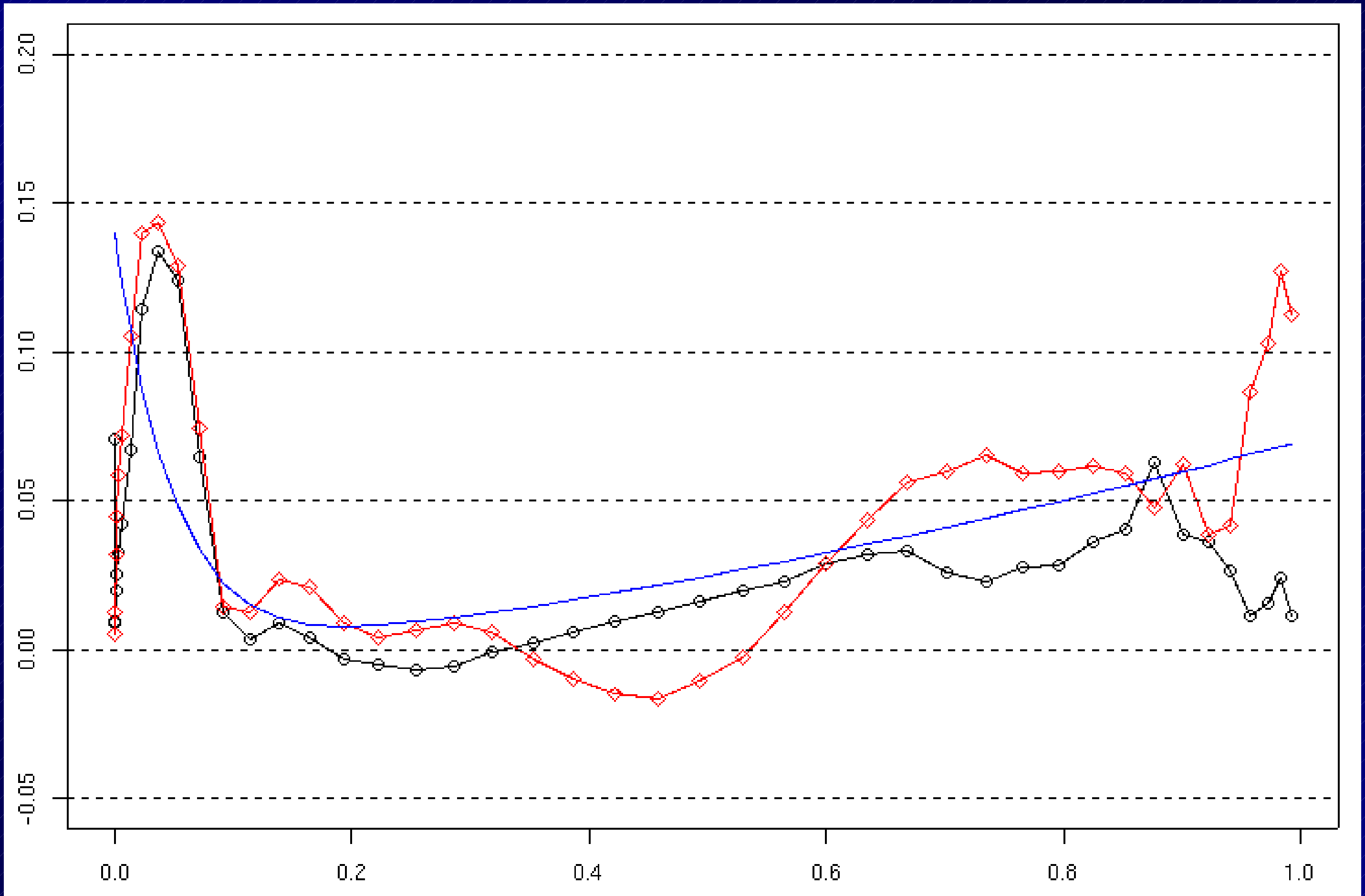
$$\alpha = N\left(\frac{p}{p_s}\right) + K\left(\frac{p}{p_s}\right)\frac{\partial c_p \Theta}{\partial \varphi}$$

allows different treatment of troposperic and stratospheric inversions

# Fitting function for *N*



# Fitting function for *K*




*K*

EAL app.

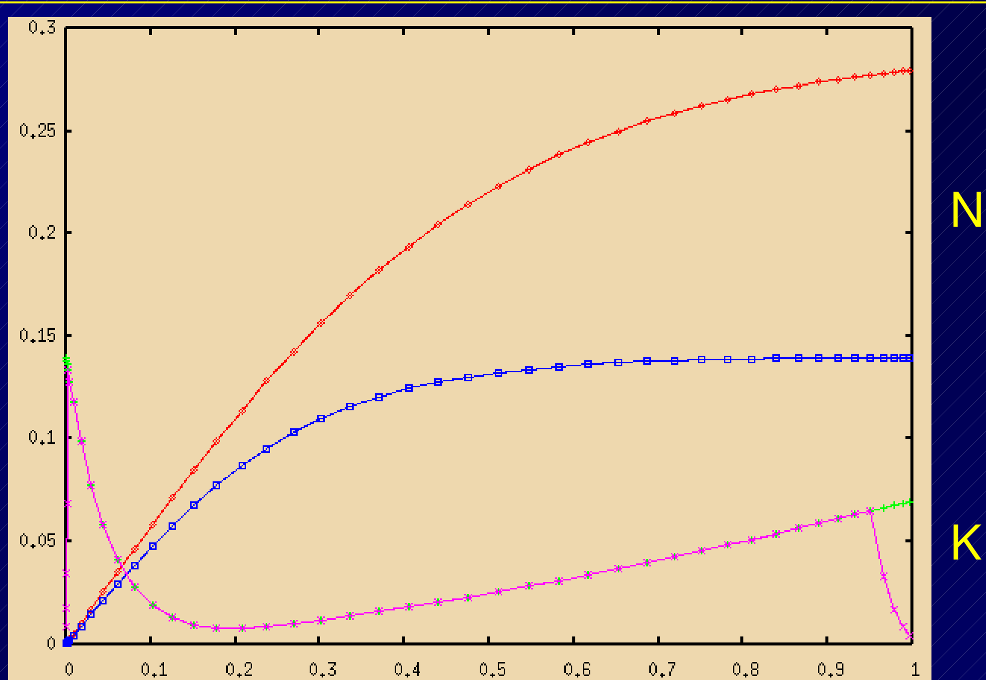
EAL exact

top

$p/p_s$

bottom

# Fitting function for *N* and *K*



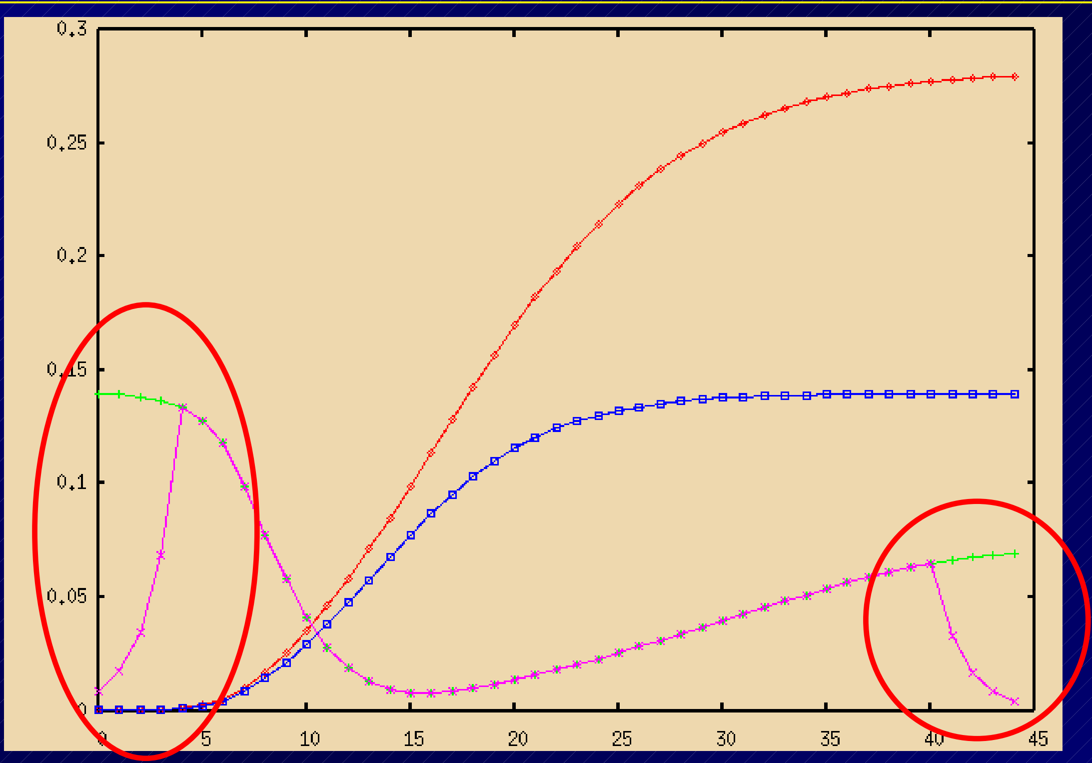

$$\alpha = 0.29\tanh\left(2\frac{p}{p_s}\right) + \left(0.07\left(\frac{p}{p_s}\right)^{1.5} + 0.14\left(1-\frac{p}{p_s}\right)^{20}\right)\left(\frac{\partial c_p \Theta}{\partial \varphi}\right)$$

EAL app.

$$\alpha = 0.14\tanh\left(3.5\frac{p}{p_s}\right) + \left(0.07\left(\frac{p}{p_s}\right)^{1.5} + 0.14\left(1-\frac{p}{p_s}\right)^{20}\right)\left(\frac{\partial c_p \Theta}{\partial \varphi}\right)$$

EAL exact

# Fitting function for *N* and *K*

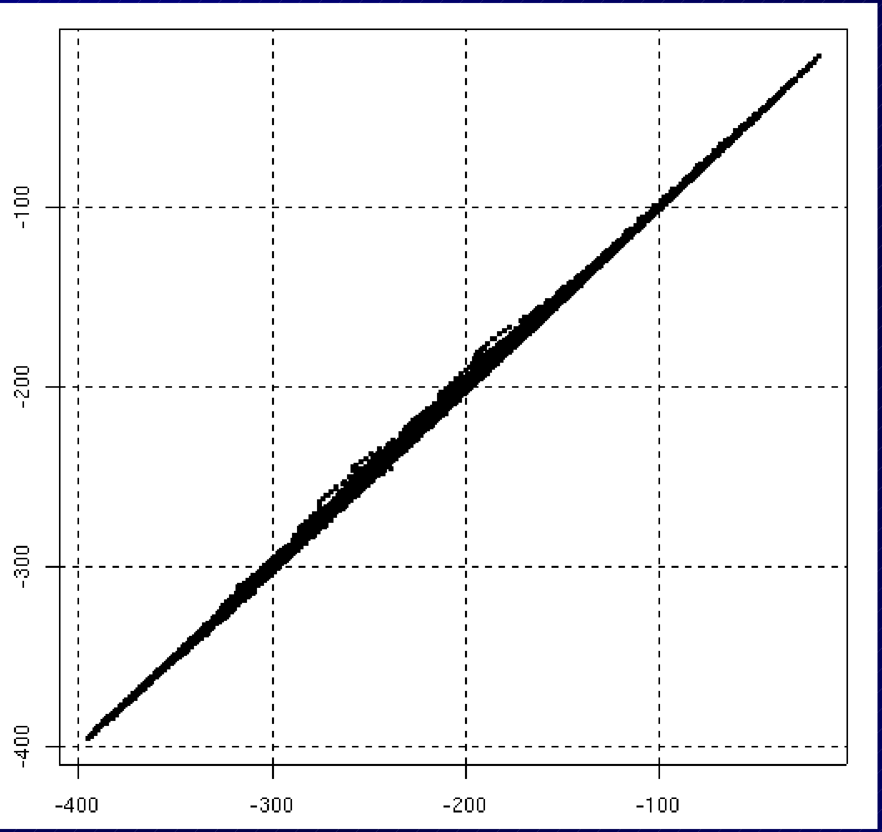



Pushed towards 0 at the edges to prevent double counting of local effect for EAL=exact

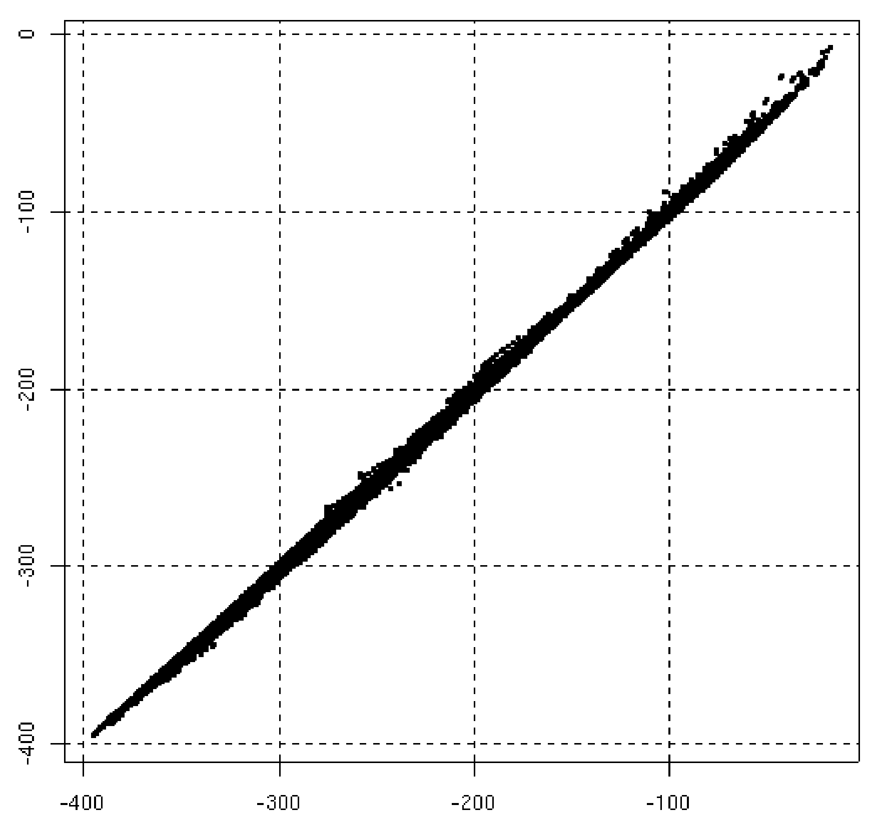
# Results

parameterized versus computed thermal flux

Version 2




Version 1



# Geopotential - RMSE

## Comparison between statistical fit 1 and 2

Only in geopotential

Slight improvements in stratosphere

Only 4 days