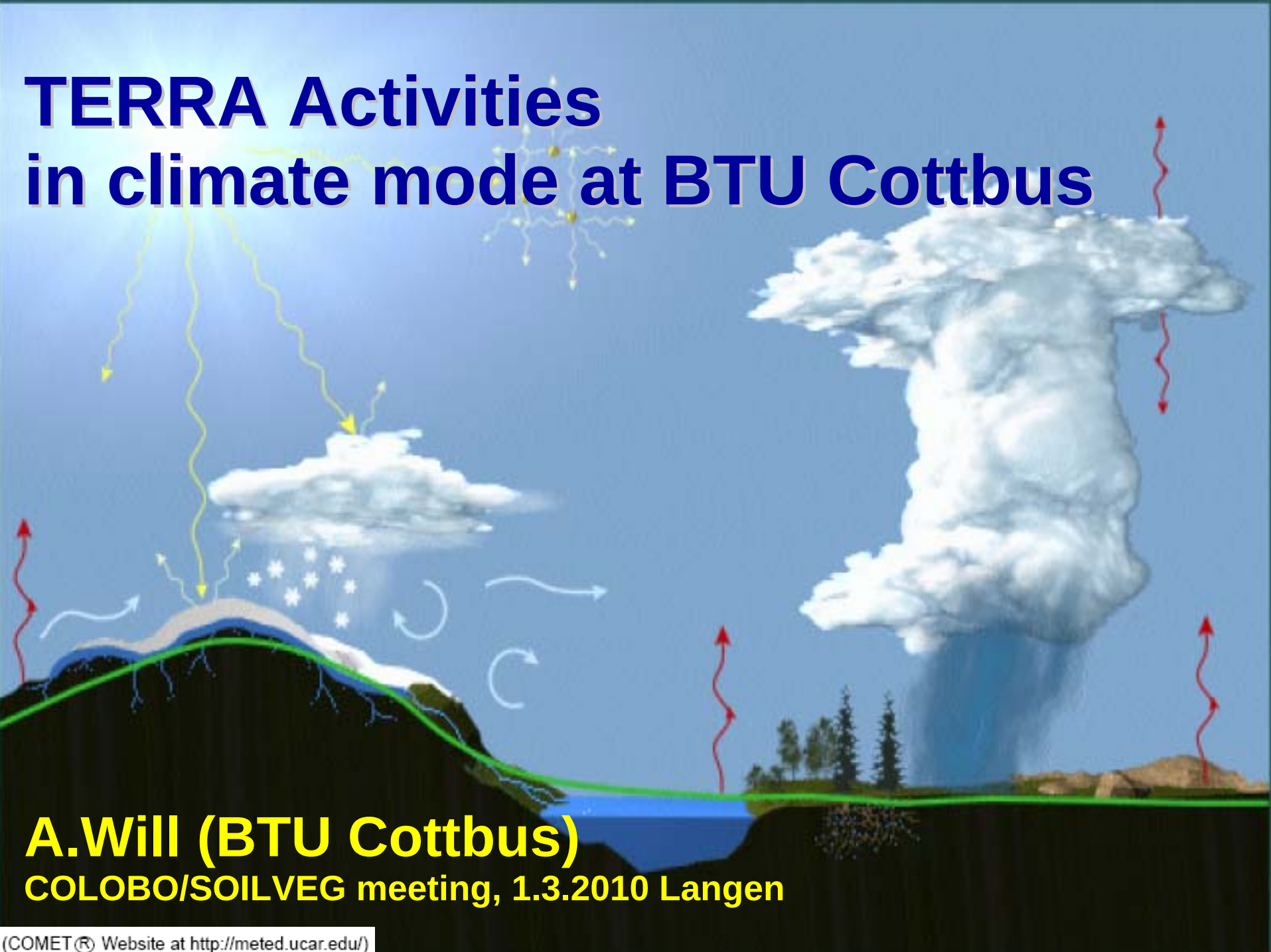
# TERRA Activities in climate mode at BTU Cottbus



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**COLOBO/SOILVEG meeting, 1.3.2010 Langen**

(COMET® Website at http://meted.ucar.edu/)


# Overview

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1. Optimal configuration for TERRA
2. Land use changes (lakes) at high resolutions in Brandenburg
3. Evaluation of new model version

# 2 Physics of the soil model TERRA

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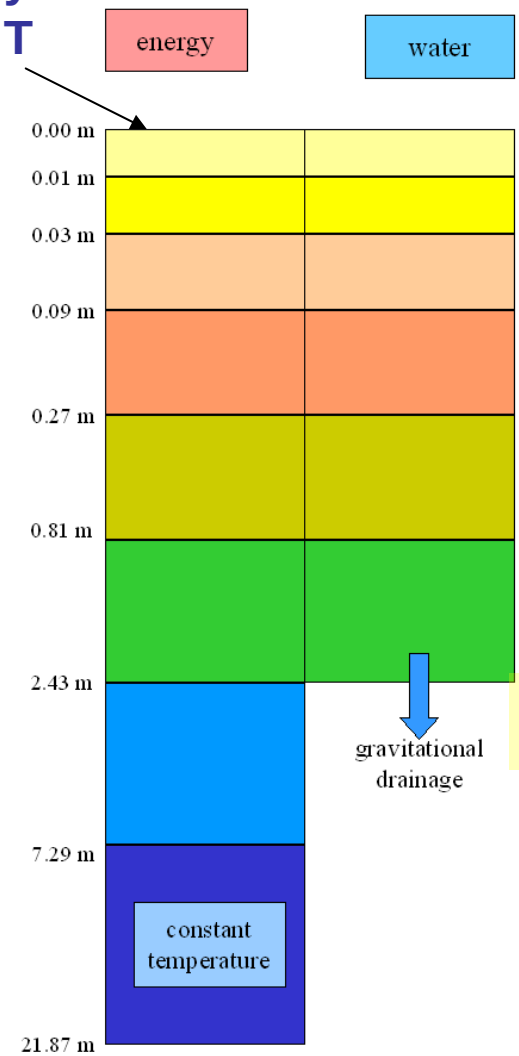
**Free boundary condition for T**

**Oper. Config:**

$\Delta z_1$=0.01

NWP:
$\Delta z_k/\Delta z_{k+1}$=3
RCM:
$\Delta z_k/\Delta z_{k+1}$=2

$z_{max}$=15m




- Interception: $\rho_w \frac{\partial W_i}{\partial t} = \alpha \cdot P + E_i - I - R_i$
- Snow:
  $\rho_w \frac{\partial W_{snow}}{\partial t} = P_{snow} + E_{snow} - I_{snow} - R_{snow}$
- Subsurface Water:
  $\rho_w \frac{\partial W_1}{\partial t} = E_b + I_{snow} + I_{perc} +$
  $(1-\alpha)P - R_{infil} + F_{1,2} - Tr_1 - R_1 + S_1$
- Soil Water:
  $\rho_w \frac{\partial W_k}{\partial t} = F_{k,k+1} - F_{k-1,k} + Tr_k - R_k + S_k$
- Soil Ice: $\rho_w \frac{\partial W_{ice,k}}{\partial t} = -S_k$
- Soil Temperature: $\frac{\partial T_{so}}{\partial t} = \frac{1}{(\rho c)} \frac{\partial}{\partial z}\left(\lambda \frac{\partial T_{so}}{\partial z}\right)$
- Surface Flux Forcing:
  $Q_{sfc} = Q_{rad} + c_p H + LE + G_P + G_{snow,melt}$

# 2.2 Solution of the heat conduction equation for homogenous soil and wave forcing



$$\frac{\partial T_{so}}{\partial t} = \frac{1}{C}\frac{\partial}{\partial z}\left(\lambda \frac{\partial T_{so}}{\partial z}\right) \longrightarrow T_{so}(z,t) = T_{CL} + (T_0 - T_{CL}) e^{-z/D} e^{i(\omega t - z/D)}$$

$$k = 1/D = 2\pi/L$$

$$D^2 = \frac{2\lambda}{\rho c\, \omega}$$

**Req.:** $$\Delta z \leq L/(2 \cdot m) = \frac{1}{m}\sqrt{\frac{2\pi\lambda}{\rho c}}\sqrt{\Delta t}$$

$$\Delta z_1 \leq \sqrt{\frac{2\pi\lambda_0 \Delta t}{m^2 \rho_0\, c_0}} \simeq 8.3 \cdot 10^{-4}\sqrt{\frac{\Delta t}{m^2}}\frac{\mathrm{m}}{\sqrt{\mathrm{s}}}$$

**Req.:** $z \geq z_{cl} = \frac{n_{cl}}{2} D_{rock}$ with $D \leq D_{rock} = \sqrt{2/\pi(\lambda_0/\rho_0 c_0)_{rock}}\sqrt{\Delta t} \simeq 8.5 \cdot 10^{-4}\sqrt{\Delta t}$

# 3. Optimal configuration

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3.1 Thickness of the upper soil layer $\Delta z_1$

3.2 Soil depth $z_{max}$

# 3.1 Thickness of the upper soil layer and soil depth

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## Resolution of relevant forcings (d,y, turb.)

| Configurations | COSMO -EU | COSMO -DE | CLM-E / CLM-K | Forcing frequency | | | |
|---|---|---|---|---|---|---|---|
| $\Delta_x$ [km] $\omega$ | 2.2 | 7 | 18 | d | y | 10y | 100y |
| $\Delta_{atm}t$ [m/s] | 25 (RK) | 40 (LF) | 90 (LF) | | | | |
| $\Delta_f v$ [m/s] | 14 | 14 | 10 | | | | |
| $\Delta_f t$ | 150 s | 500 s | 0.5 h | 0.5 d | 0.5 y | 5 y | 50 y |
| $T_0$ [K] | 1 | | | 20 | 40 | 3 | 1 |
| $m_0$ | 1 | | | 8 | | 4 | 1 |
| $n_{cl}$ | 2.3 | | | 5.3 | 6 | 3.4 | 2.3 |
| $D_{clay}$ [m] | 0.0033 | 0.0059 | 0.011 | 0.055 | 1.1 | 3.3 | 11 |
| $D_{rock}$ [m] | 0.010 | 0.019 | 0.036 | 0.18 | 3.4 | 11 | 34 |
| $\Delta_1 z$ [m] | 0.01 | 0.019 | 0.035 | 0.017 | 0.41 | 2.6 | 33 |
| $z_{cl}$ [m] | 0.012 | 0.022 | 0.042 | 0.47 | 10 | 18 | 39 |

**Results consistent with literature and practice!**

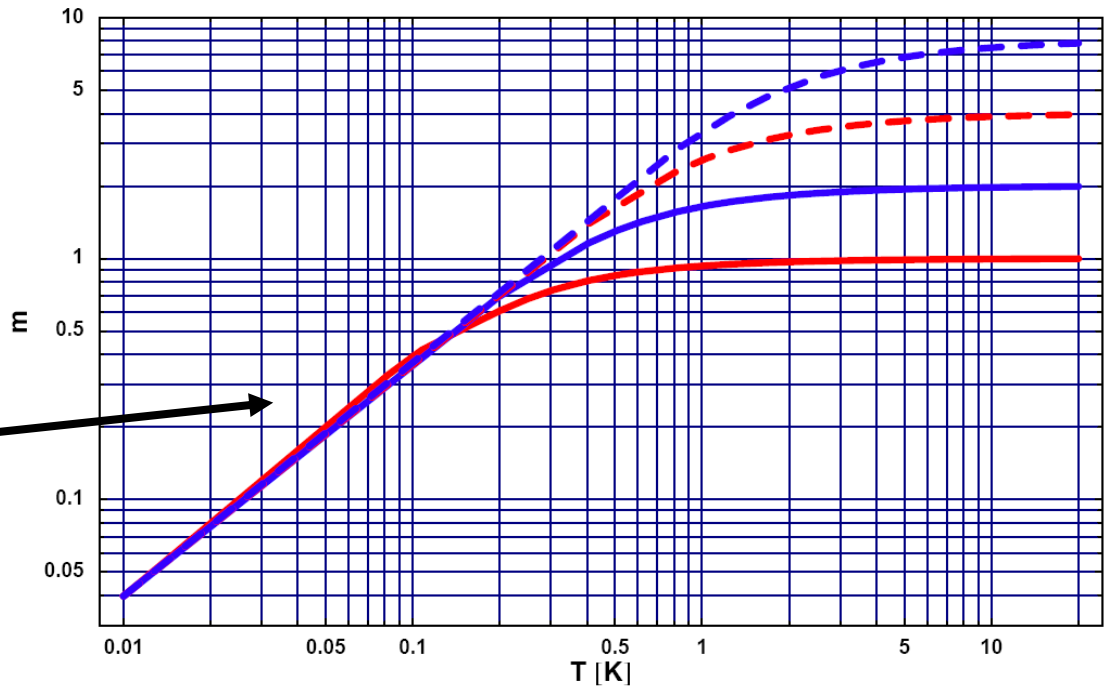
# 3.3 Linear grid stretching $\Delta z_k/\Delta z_{k+1}=b$



$$z_{m,k} = \left(\frac{b^i - 1}{b-1} - \frac{b^{i-1}}{2}\right)\Delta_1 z \simeq \frac{b+1}{2(b-1)}\Delta_k z.$$

**Comparison**

$$\Delta_{st,f} z(z) \leq \frac{\pi}{m_{st,f}(T(z))} D_{st,f}$$



# 3.3 Linear grid stretching $\Delta z_k/\Delta z_{k+1}=b$

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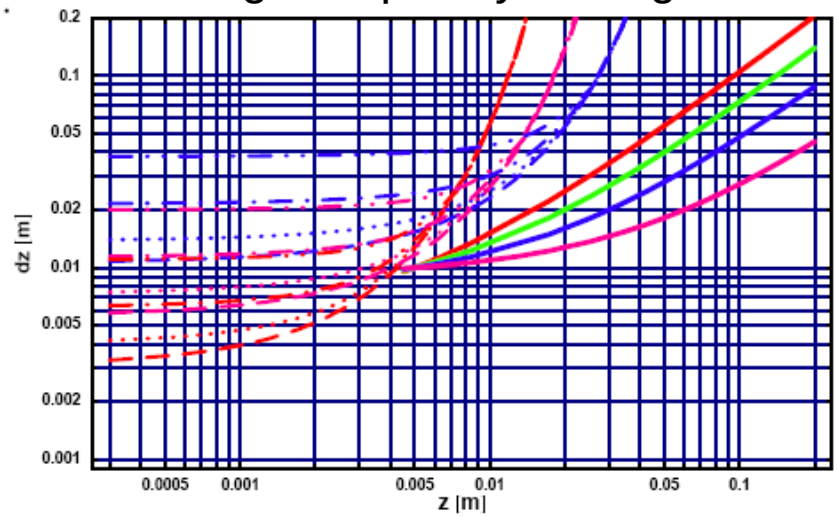
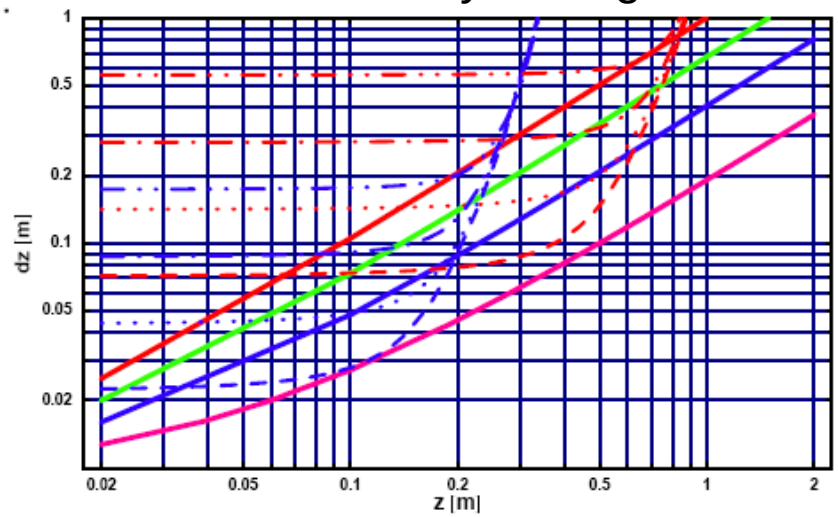
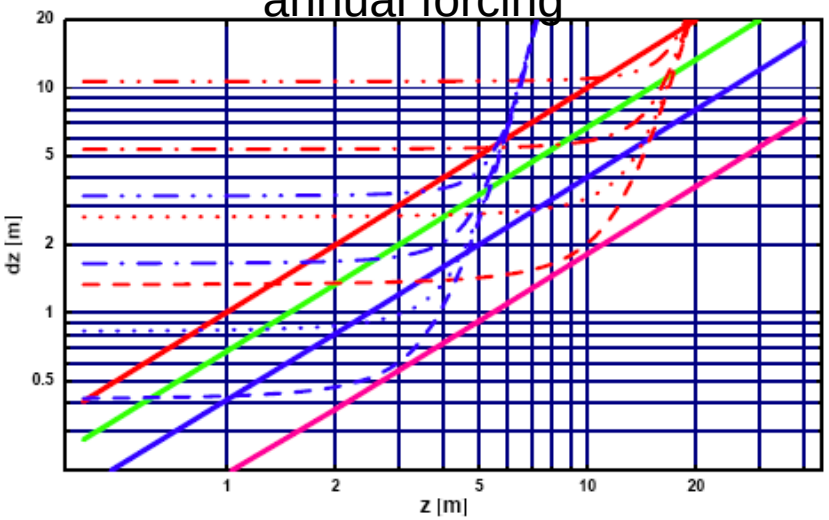
A. High frequency forcing



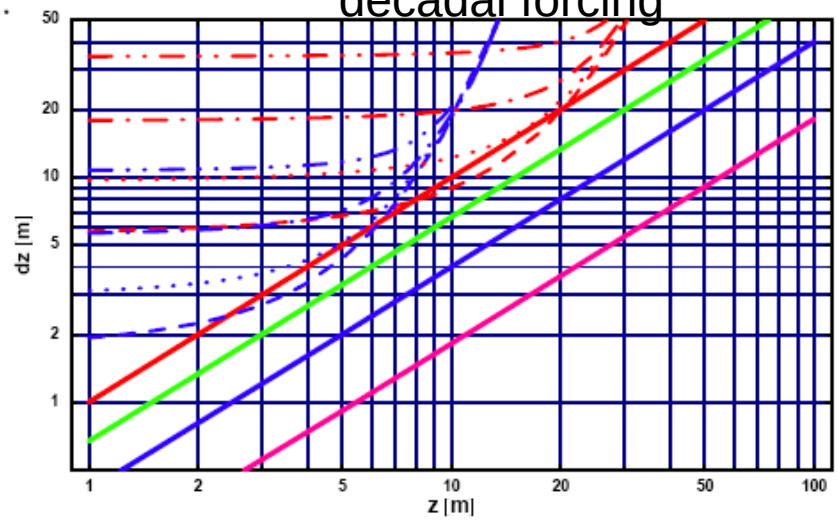

B. daily forcing




C. annual forcing



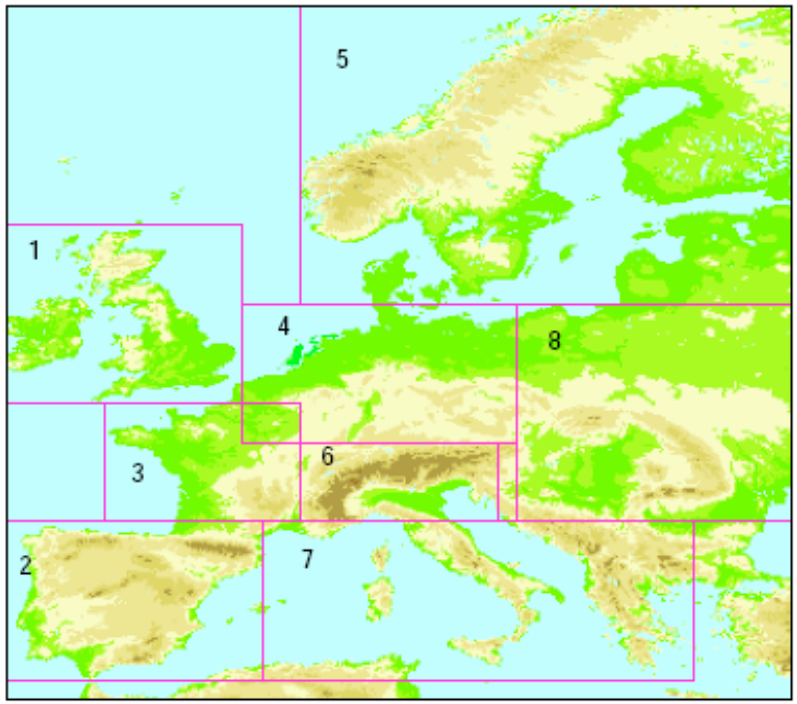

D. decadal forcing

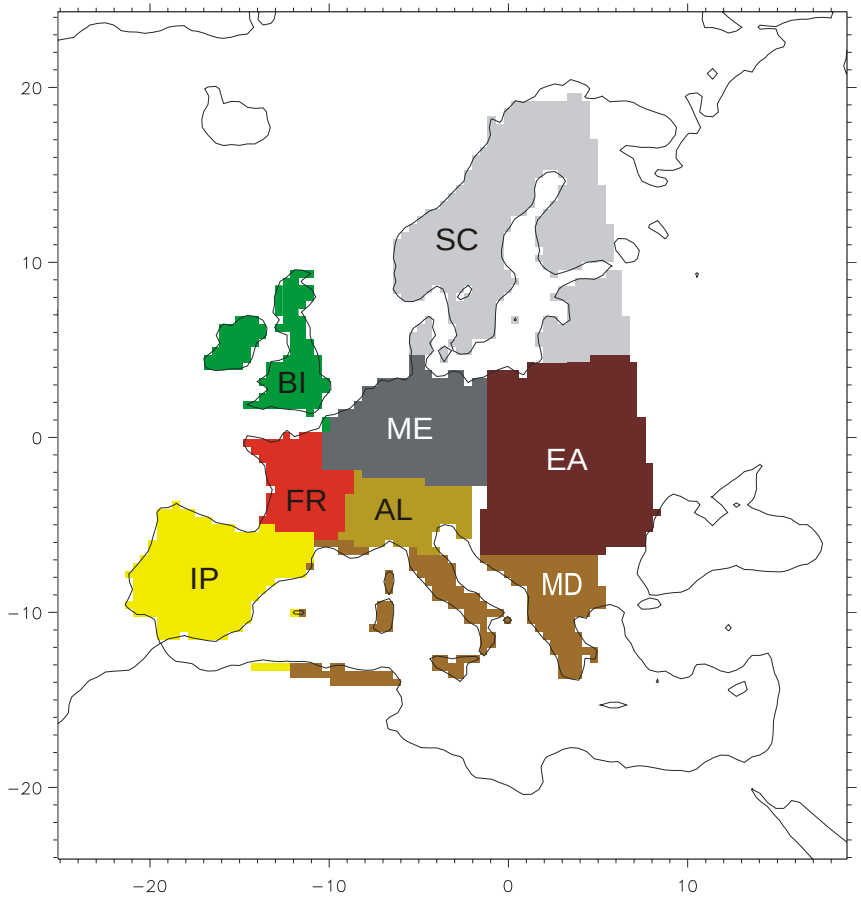



**b= 3, 2, 1.5, 1.2**

# 4. Results, 4.1 Regions

## 1964-1973



# 4. Results at dx=dy=50km
# 4.2Configuration

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| | | | | |
|---|---|---|---|---|
| Simulation period | 1959-1973 | | | |
| Evaluation period | 1964-1973 | | | |
| Dynamics: | Runge-Kutta (RK) and Leapfrog (LF) | | | |
| Soil configurations: | | $\Delta z_1$=0.01; $z_{max}$=15m | | |
| Grid Stretching | $\Delta z_k/\Delta z_{k+1}$: | 2, | 1.5 | 1.2 |
| Number of layers: | | 10 | 17 | 33 |
| Model version: | cosmo_4.8_clm7 | | | |
| | with RK dry bias and LF wet bias | | | |

## 4.2 Soil Temperature at z=0.11m

- annual cycle
- daily cycle

# 4.2 $T_{so,X}$ (z) - $T_{so,LF-2}$ (z)
## 1964-1973, z=0.11m

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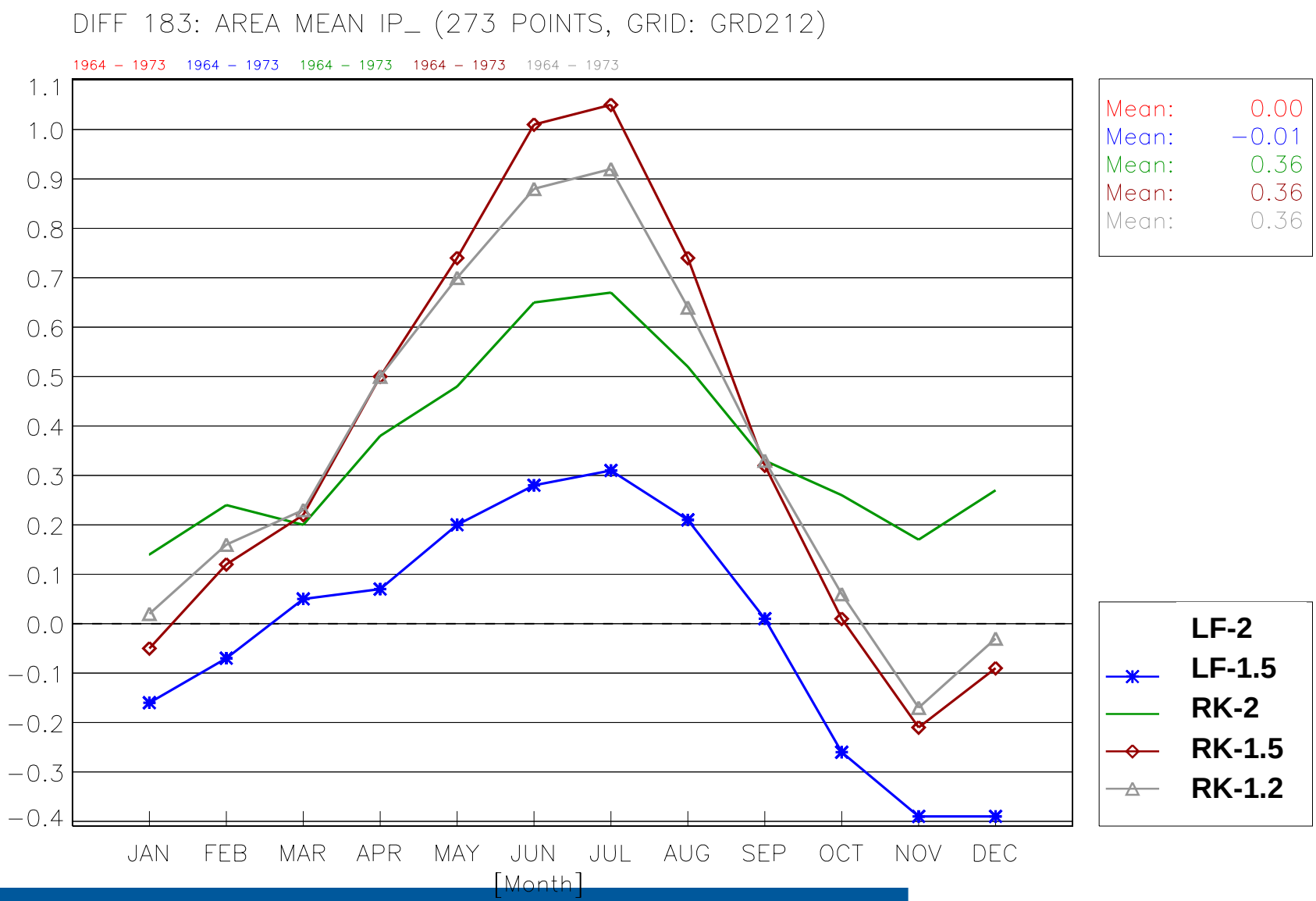
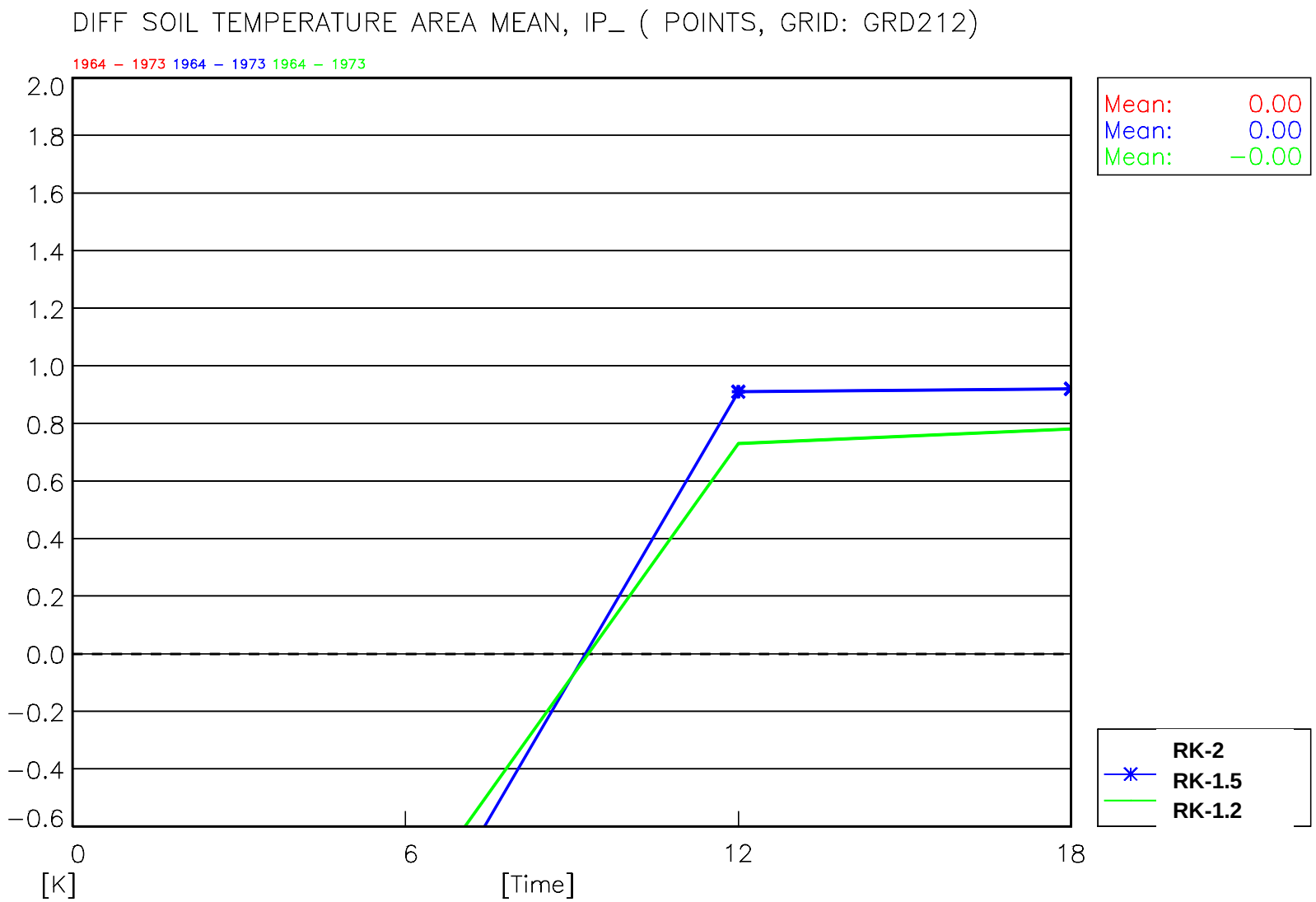


# 4.2 $T_{so,LF-1.5}$ (z) - $T_{so,LF-2}$ (z)
## 1964-1973, z=0.11m



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## 1964-1973, z=0.11m

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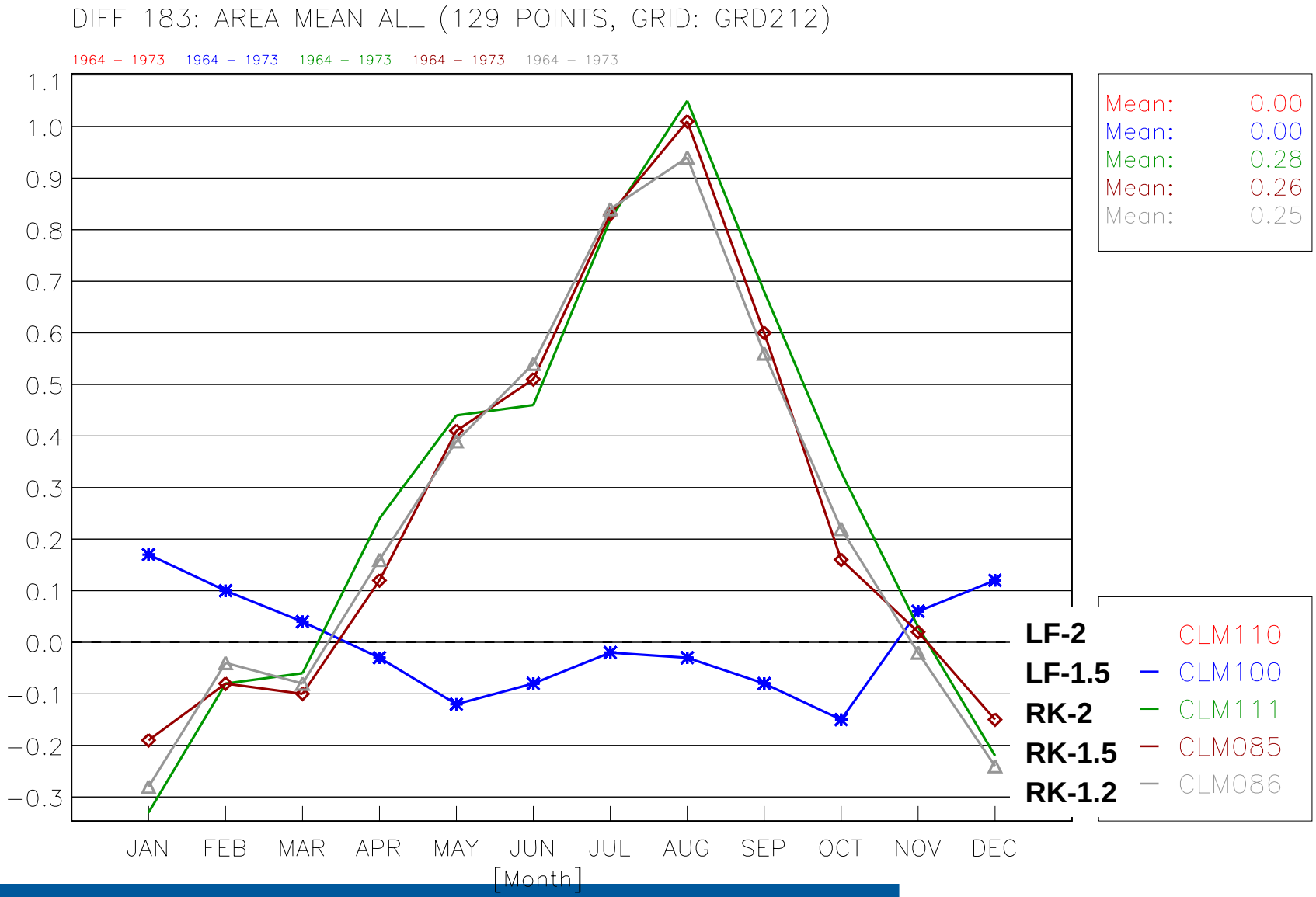
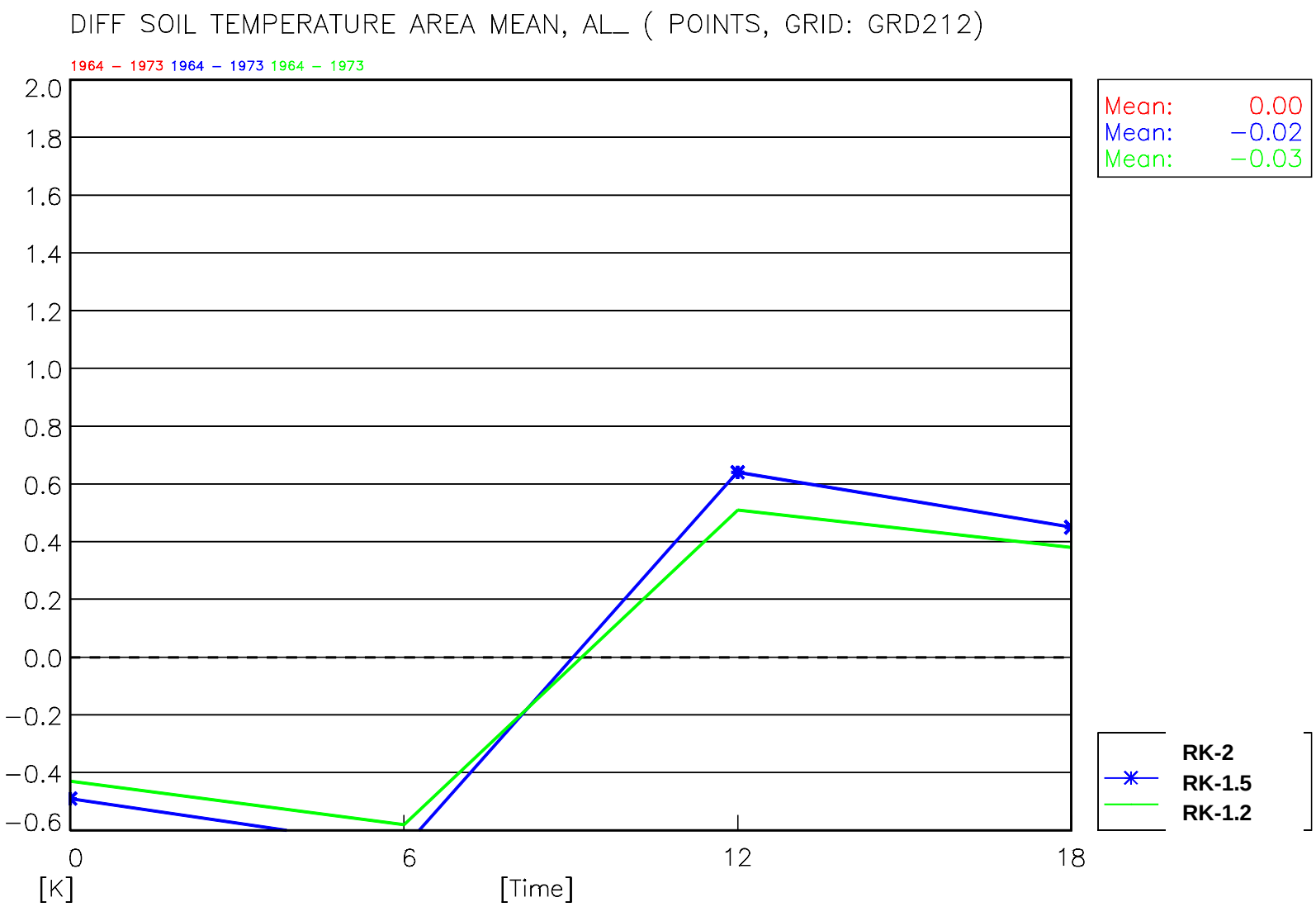


# 4.2 $T_{so,LF-1.5}$ (z) - $T_{so,LF-2}$ (z)
## 1964-1973, z=0.11m



# 4.3 $T_{2m,LF-1.5}(z) - T_{2m,LF-2}(z)$ 1964-1973

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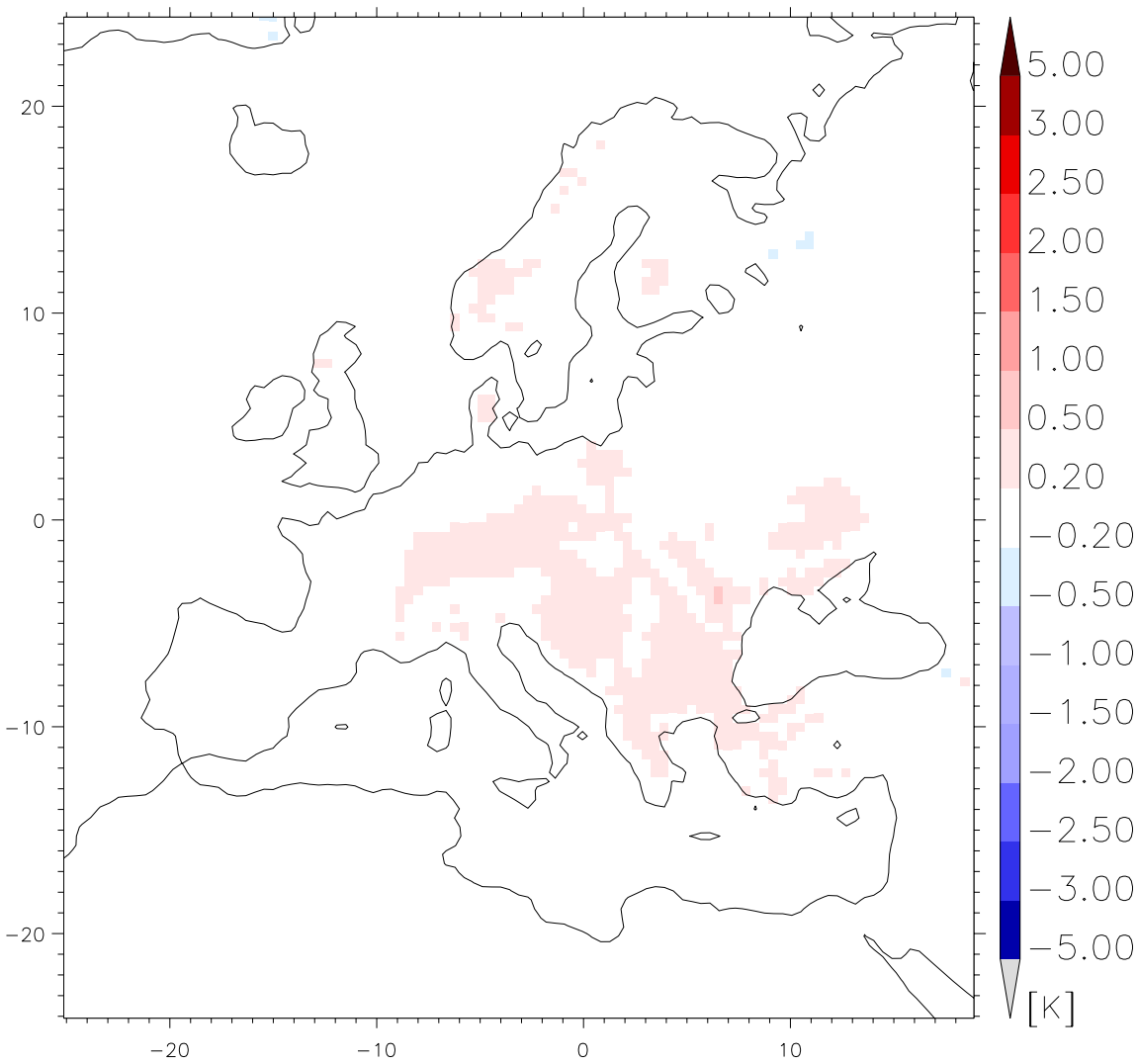

# 4.3 $T_{2m,x}(z) - T_{2m,ECAD}(z)$ 1964-1973, ME

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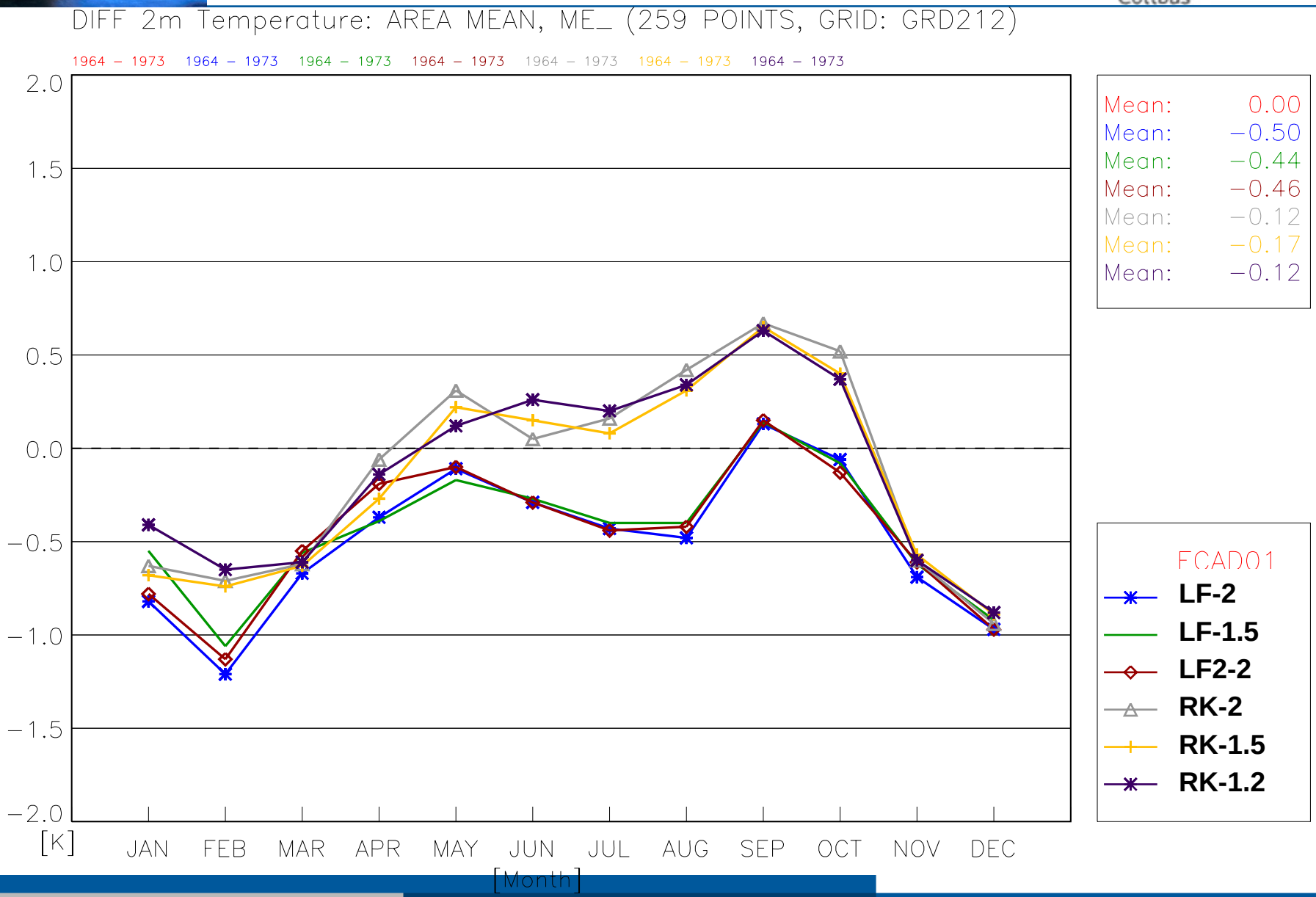

# 4.4 $PREC_{LF-1.5}(z) - PREC_{LF-2}(z)$
## 1964-1973, ME

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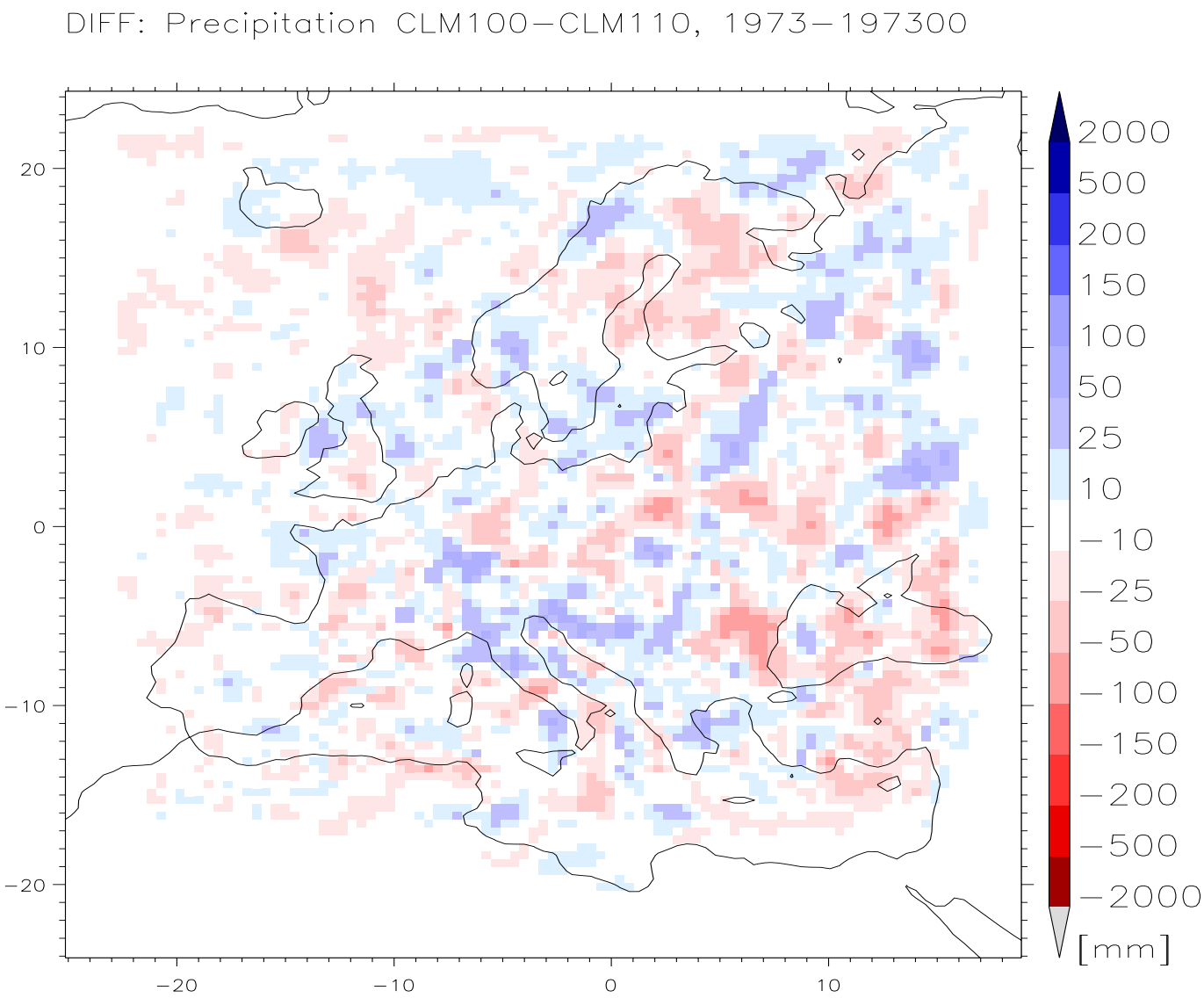

# 4.4 $PREC_X(z) - PREC_{ECAD}(z)$
## 1964-1973

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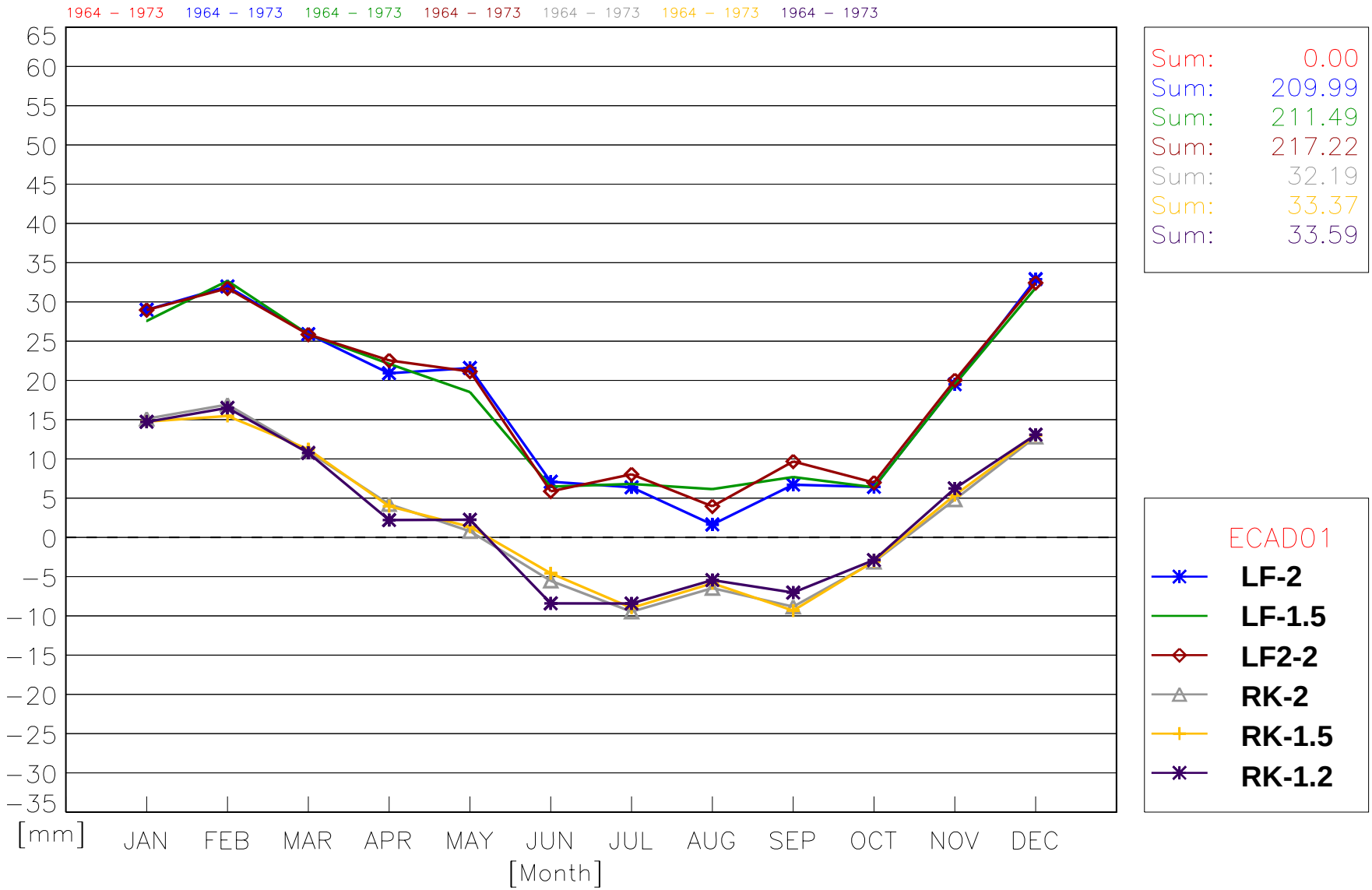

# Summary



1. **Grid configuration parameters** can be derived for a homogeneous soil from the analytical solution of the heat conduction equation
2. **Upper soil layer thickness** of 0.01 m is adequate for most applications
3. **Soil depth** required depends on the time scale of the simulation and a 20 m deep soil is suficient for most applications.
4. **Grid stretching** between 2 and 3 is a compromise. An optimal configuration requires a stretching between 1.2 and 1.5. A variable grid stretching would be even more appropriate. Grid stretching of 1.5 is recommended for the global and the regional model.
5. **Simulation Results** of coarse grid climate simulations (50 km, 15 y) show at 0.11m depth for 1.5 in comparison with 2.0 grid stretching factor
    1. no significant effect on the mean values
    2. no systematic significant effects on monthly precipitation and 2m temperature.
    3. significantly higher spatial and temporal mean wave aplitudes:
        1. 0.4 K for the annual cycle
        2. 0.5 to 1 K for the daily cycle

**Grid stretching seems to be not relevant for the near surface atmospheric variability. However, the soil temperature dynamics might have a stronger influence at more realistic variability in the soil and at smaller space scales.**

# Future Plans

1. **TERRA configuration**
    1. **High resolution simulations for 18km, 9km**
    2. **New TERRA version at 50km/18km: lambda (w_so)**
    3. **New TERRA version with vertical texture -> Stronger daily cycle**

2. **Evaluation of the New TERRA version -> see 1.2**
    1. **Series of 50km simulations**
    2. **One 18km simulation**

3. **Land Use Change (already started)**
    1. **Preparation of Flake parameters for the 2.8km grid of Brandenburg**
    2. **Simulations**
        1. **7km and 2.8 km**
        2. **Relevance of the Flake model for the regional climate**