Offline sensitivity studies on root parameterisation in the TERRA module

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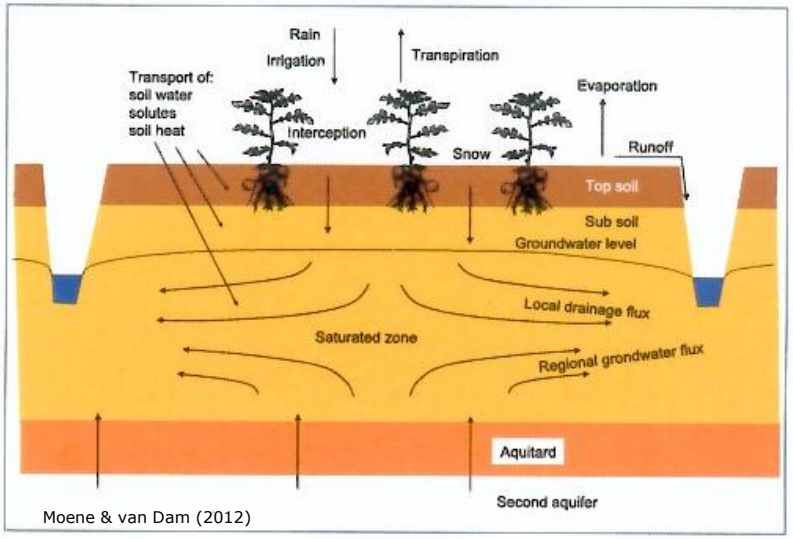
Motivation

Large impact of vegetation on energy- and water exchange between soil and atmosphere (water cycle, radiation, dynamics)

Above-ground properties:	plant cover leaf and stem biomass stomata resistance aerodynamic roughness albedo shading of the surface
Below-ground properties:	total root biomass vertical profile of root density depth of rooting zone

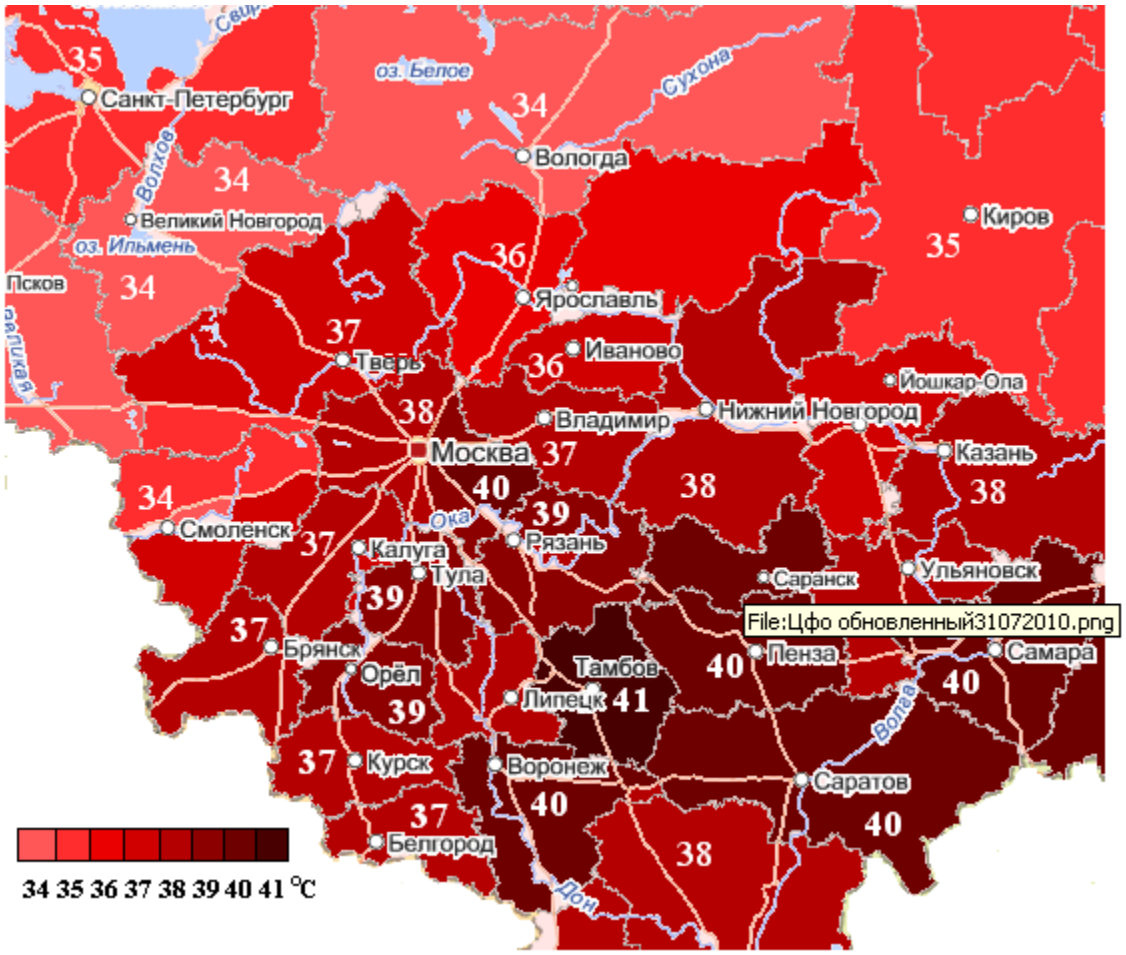


Moene & van Dam (2012)

Atmospheric models (weather, climate) need a reliable root parameterization in order to realistically represent the main vegetation effects in the annual cycle.

Heat wave in European Russia 2010

Temperatures at July 31, 2010



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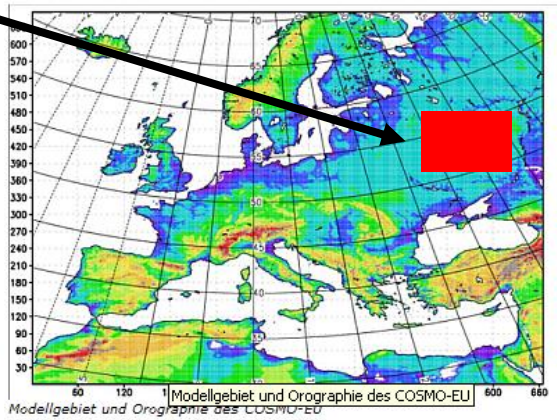
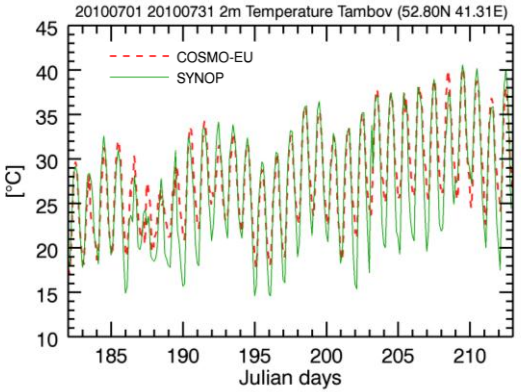
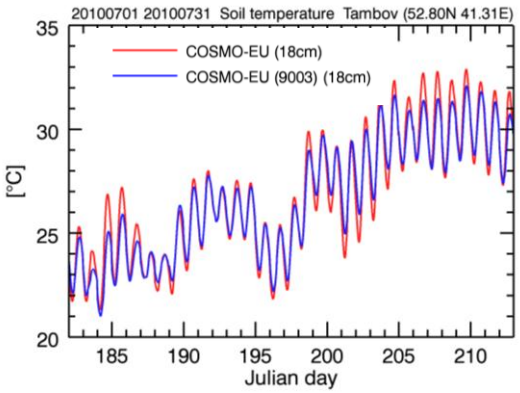
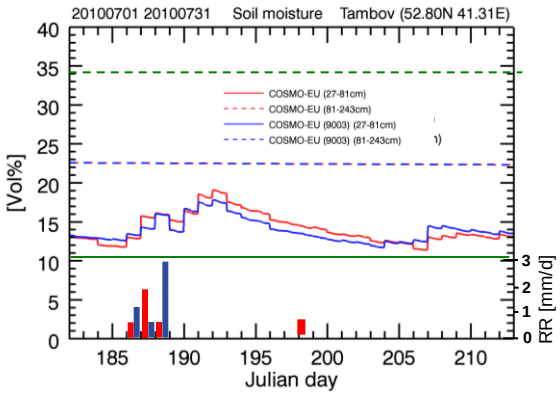
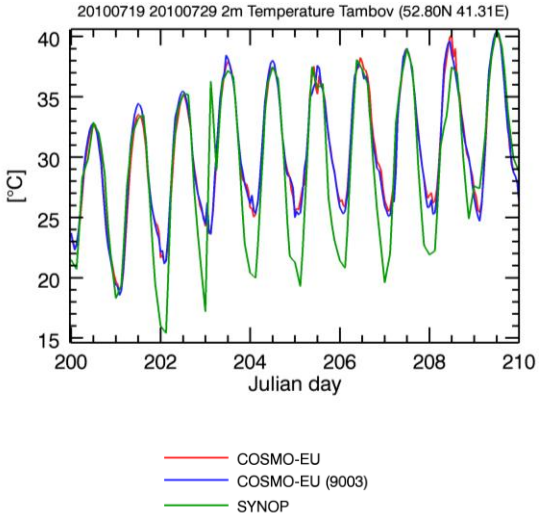


Source:Wald- und Torfbrände inRussland 2010 – Wikipedia.mht









Findings:

- daily temperature maximum (2m) well captured
- SMA artificially increases soil moisture in upper layers
- Large daily amplitudes of soil temperature
- morning temperatures strongly overestimated

How can we improve the model behaviour?

- more realistic thermal conductivity
- improved parameterisation of soil water uptake by roots
- shading effect by vegetation should be considered

Transpiration parameterization (Dickinson 1984)

$$E_{Tr} = \frac{LAI}{LSAI}\left(\frac{r_{la}}{r_{la}+r_s}\right)E_{pot}$$

$$\overline{w}_r = \frac{1}{d_{\max}}\int_{d_{\max}}^{0} r_f\, w_r\, dz$$

Present variants

Vertically constant root fraction with varying max. depth (COSMO-EU)

$$r_f = 1$$

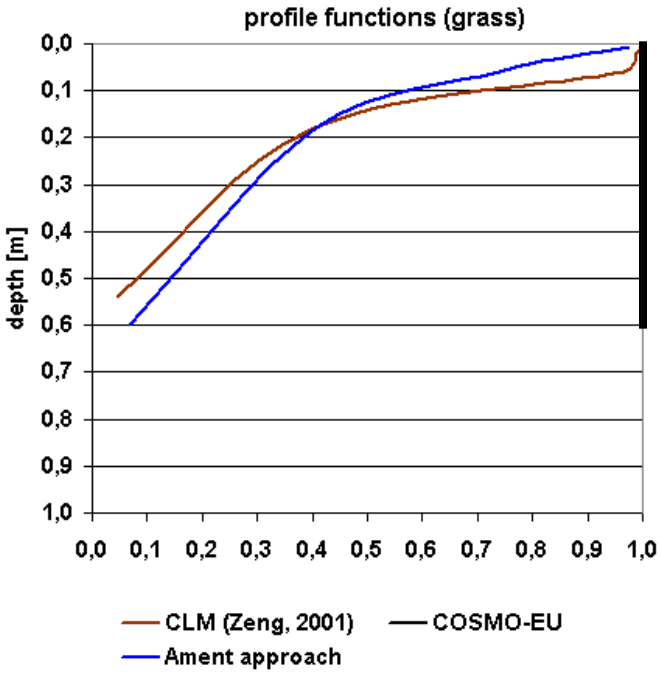
Exponential decrease of root fraction with depth, but varying max. depth (optional in TERRA V4.13)

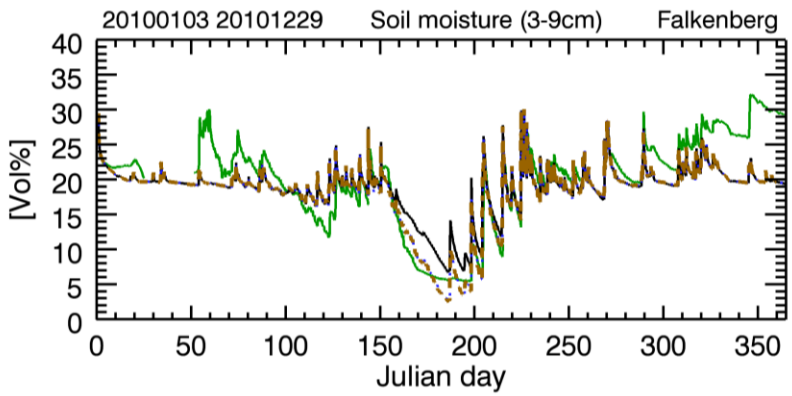
$$r_f(z_{i-1}, z_i) = e^{-\frac{3}{z_{\max}}\frac{(z_{i-1}+z_i)}{2}}$$

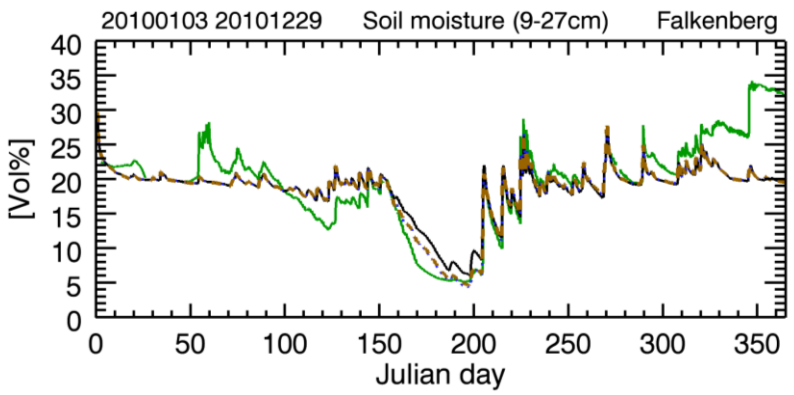
Exponential decrease of root fraction with depth (Zeng, 2001, CLM)

$$r_f(z_{i-1}, z_i) =$$

$$0.5\left[e^{-r_a z_{i-1}} + e^{-r_b z_{i-1}} - e^{-r_a z_i} - e^{-r_b z_i}\right]$$




20100103 20101229 Soil moisture (3-9cm) Falkenberg
[Vol%]
Julian day


20100103 20101229 Soil moisture (9-27cm) Falkenberg
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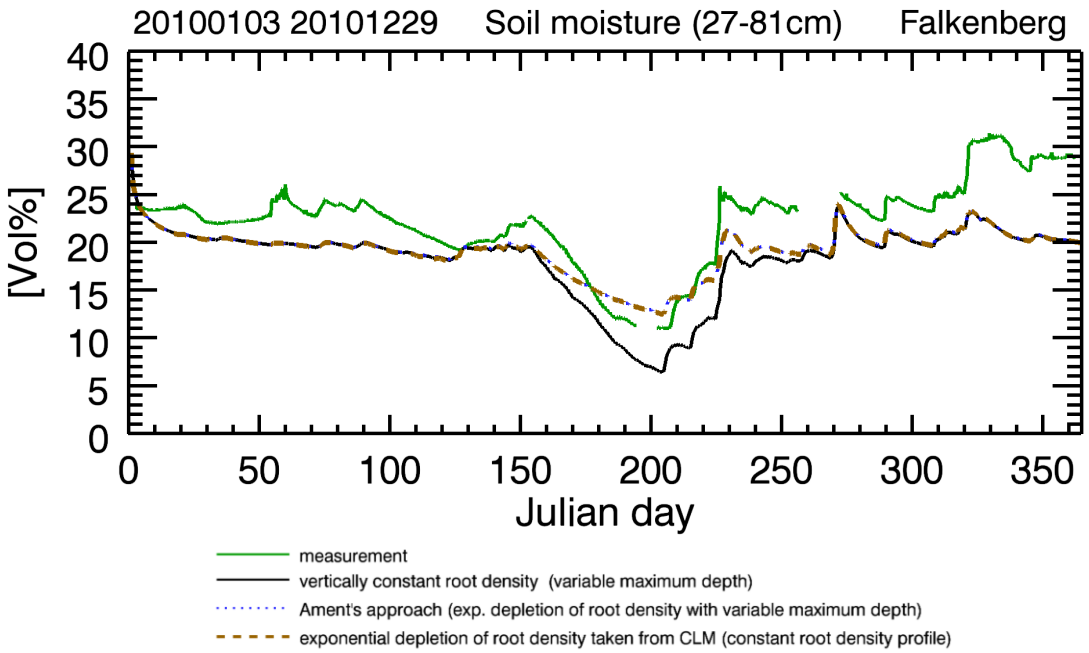
Julian day


20100103 20101229 Soil moisture (27-81cm) Falkenberg
[Vol%]
Julian day
measurement
vertically constant root density (variable maximum depth)
Ament's approach (exp. depletion of root density with variable maximum depth)
exponential depletion of root density taken from CLM (constant root density profile)

Root parameterization (Arora and Boer, 2003)

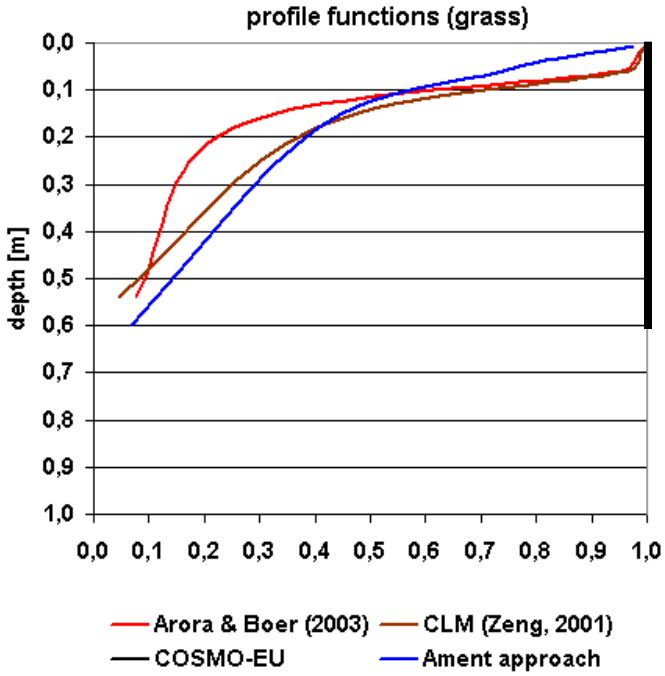
density profile [kg/m³]

$$\rho(z,t) = b B_\infty^{1-\alpha}(t) \exp\left[-\frac{b}{B_\infty^{\alpha}(t)} z\right]$$

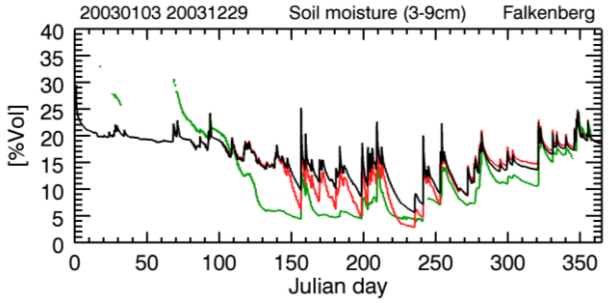
B_∞, b, α: given from field measurements for various biomes

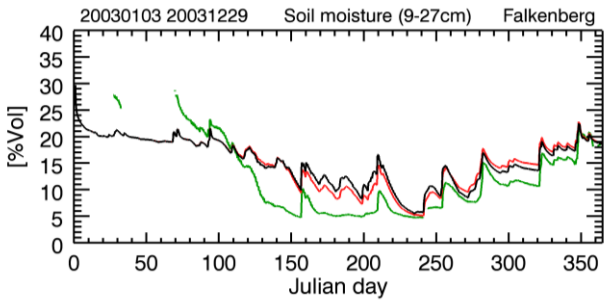
root fraction

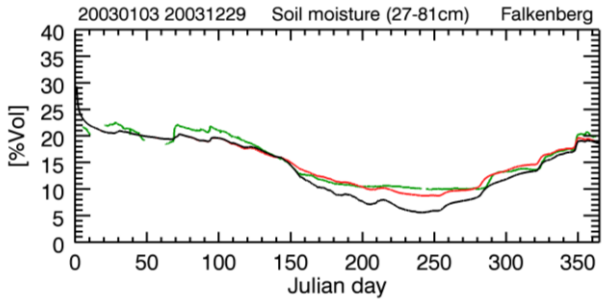
$$r_f(z_{i-1}, z_i) = e^{-\frac{b}{B_\infty^{\alpha}(t)} z_{i-1}} - e^{-\frac{b}{B_\infty^{\alpha}(t)} z_i}$$



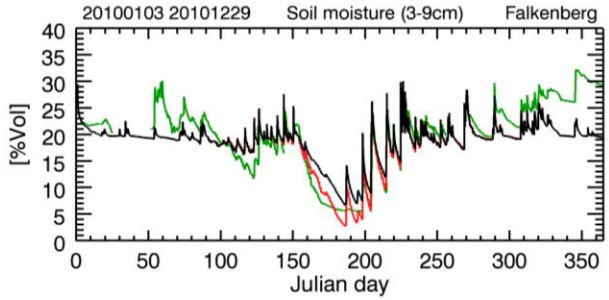
2003 (dry year)

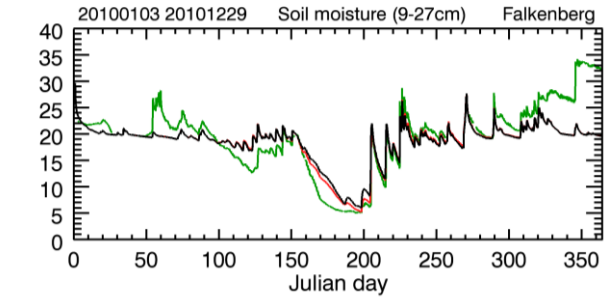


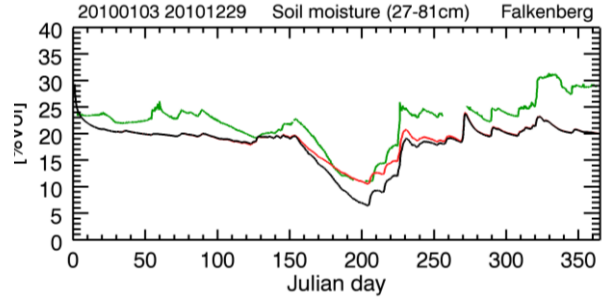




2010 (moist year)







measurement Arora & Boer COSMO root parameterization

Conclusions

• The root parameterization should only be improved in the COSMO models together with the soil heat conduction and if the shading effect of the vegetation is considered.

• A time-constant exponential root profile is sufficient in order to simulate the soil moisture development in the annual cycle.

• At present, the root parameterisation by Arora and Boer (2003) fits the annual soil moisture cycle at best. Moreover, it is open for future developments.

Many thanks for your attention!