A modified formulation for groundwater runoff in TERRA_ML

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2017-03-08

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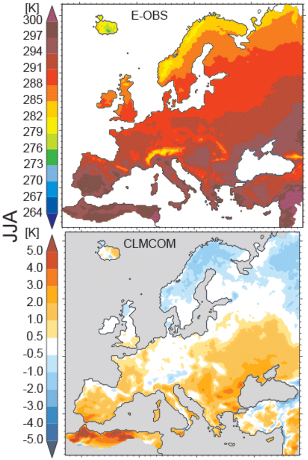
IAC Institute for Atmospheric and Climate Science

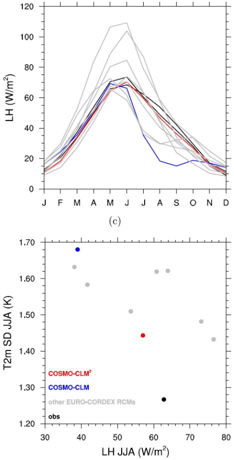
CCLM

Motivation

- Large biases in summer temperatures linked to drying of the soil

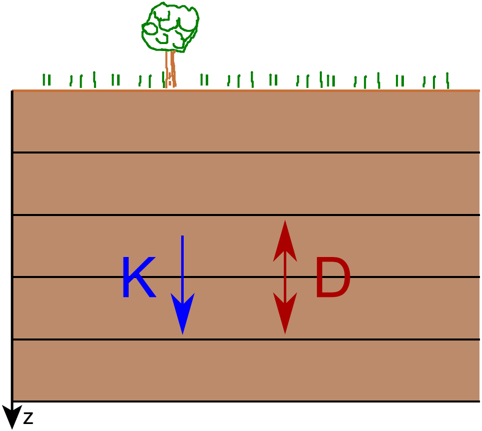


JJA T_{2m} bias EURO-CORDEX (Kotlarski, et al. 2014)



EURO-CORDEX annual cycle of latent heat flux (Davin et al. 2016)

Richards Equation



Flux divergence gives local drying/moistening:

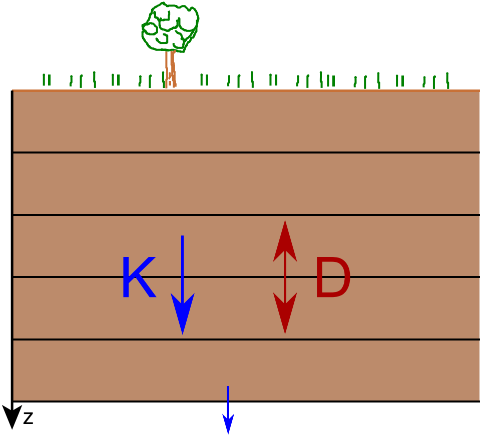
$$\frac{\partial \theta}{\partial t} = \frac{1}{\rho_w} \frac{\partial F}{\partial z}$$

soil water flux F:

$$F = -\rho_w \cdot \left[-D(\theta) \frac{\partial \theta}{\partial z} + K(\theta) \right]$$

θ : volumetric water content [m m^{-1}]
D: hydraulic diffusivity
K: hydraulic conductivity

Richards Equation



drainage as lower boundary condition

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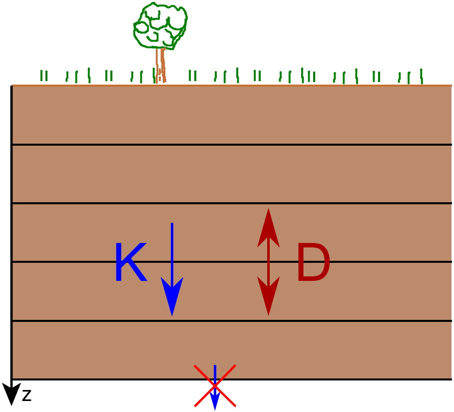

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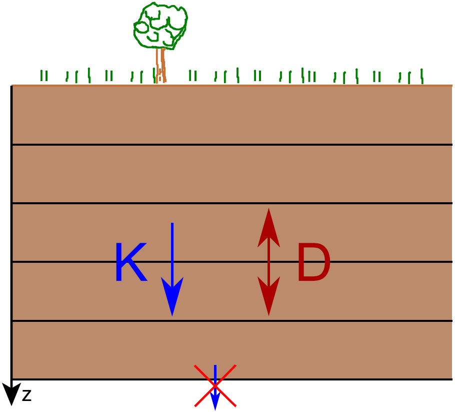


soil water flux F:

$$F = -\rho_w \cdot \left[-D(\theta)\frac{\partial \theta}{\partial z} + K(\theta) \right]$$

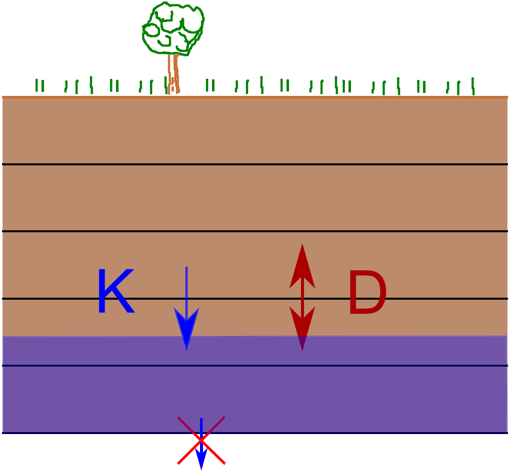
$$K(\theta) = K_0 \exp\left[K_1 \frac{\eta - \overline{\theta}}{\eta - \alpha} \right];\ K_1 < 0$$

η: porosity, α: air dryness point

$K \rightarrow K_0$ for $\theta \rightarrow \eta$

flux increases for wet soil

Limit fluxes



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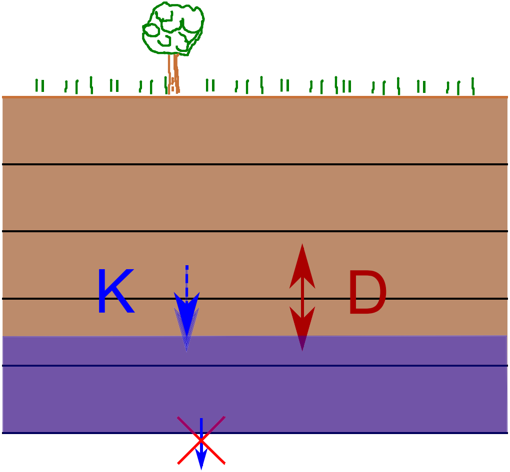

limit fluxes by limiting $K_{k-\frac{1}{2}}$

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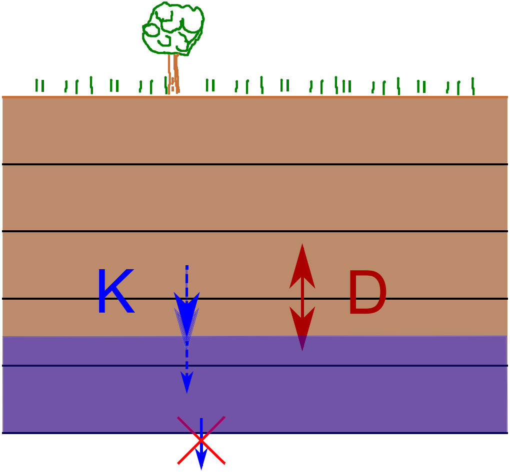

limit fluxes by limiting $K_{k-\frac{1}{2}}$

$K_{k+\frac{1}{2}}$ limited

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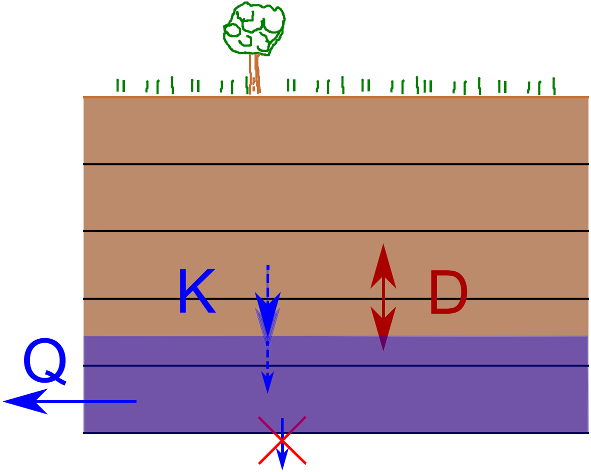


limit fluxes by limiting $K_{k-\frac{1}{2}}$

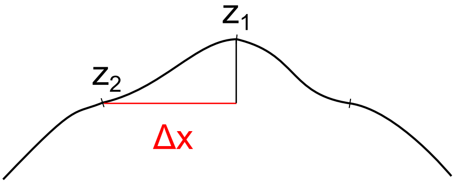
$K_{k+\frac{1}{2}}$ limited

Diagnostic runoff from ground water Q

Runoff from ground water: Q

$$Q = \gamma \cdot K_0(z) \cdot S_{oro} \cdot h_{wt}$$

γ: constant (tuning coefficient)
$K_0(z)$: saturated hydraulic conductivity
S_{oro}: gradient of (sub-grid) orography
h_{wt} : depth of groundwater layer



$$S_{oro} = \frac{max(z_1 - z_2, 0)}{\Delta x}$$

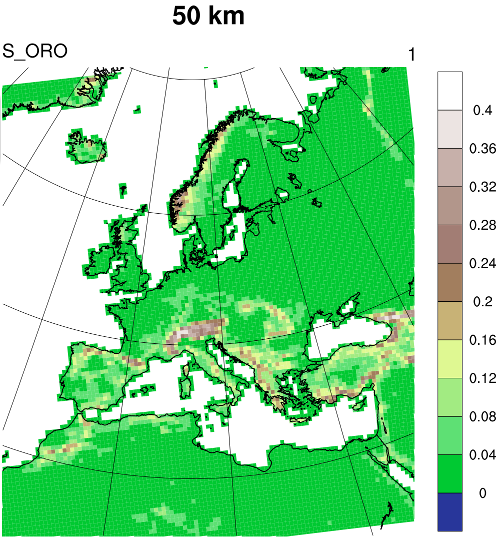
Slope parameter S_{oro}

$$Q = \gamma \cdot K_0 \cdot S_{oro} \cdot h_{wt}$$

Computed from GLOBE dataset

Computed on 0.01°×0.01°grid, then averaged over coarse grid box

minimum value of 0.001 (≙1‰) to enable runoff in flat areas



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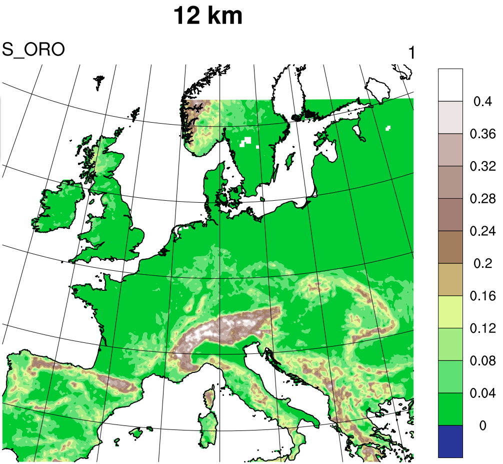

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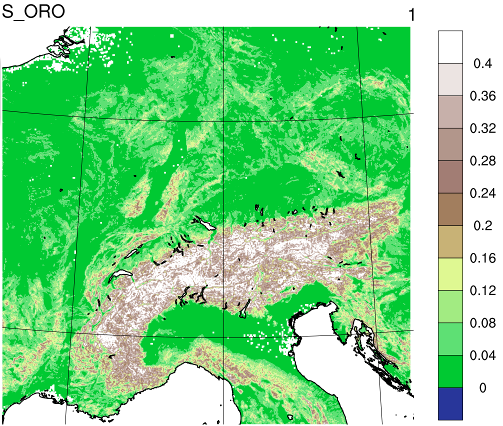
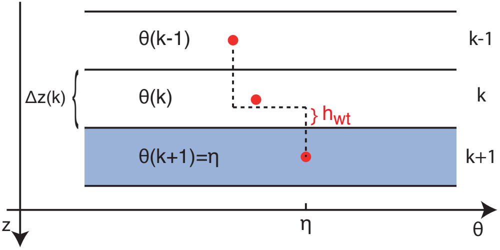
2 km



Continuous function for water table depth

Water table depth h_{wt}

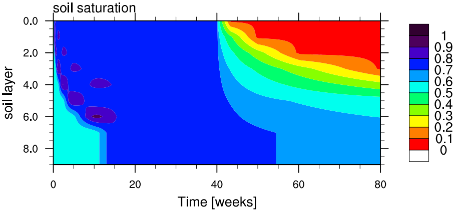
$$Q = \gamma \cdot K_0 \cdot S_{oro} \cdot h_{wt}$$



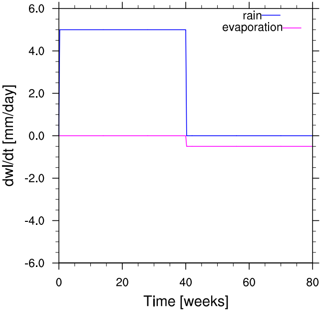
$$h_{wt} = \Delta z(k) \frac{\theta(k) - \theta(k-1)}{\eta - \theta(k-1)}$$

Tests, stand-alone single-column model

Default TERRA_ML



budget



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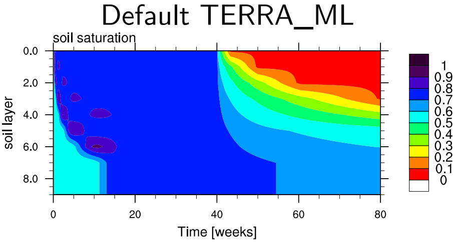

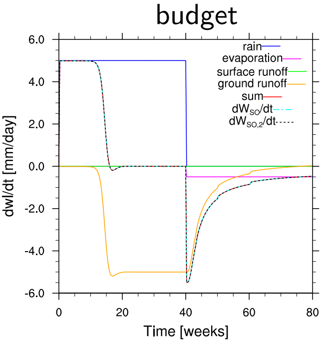

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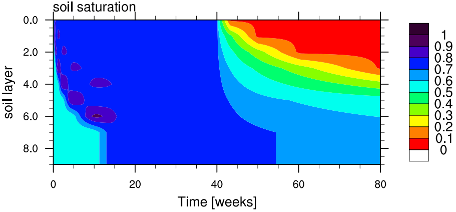
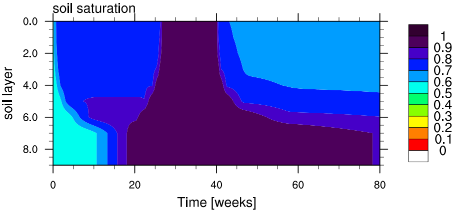


new implementation



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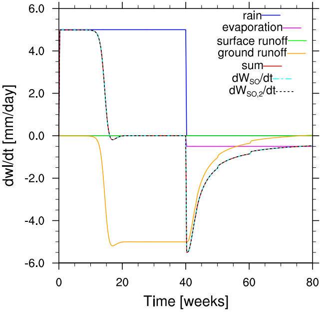

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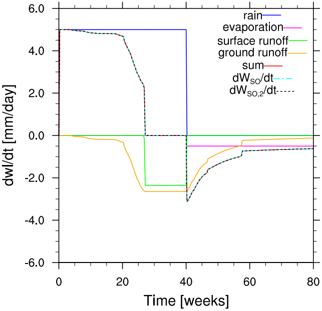

Implementation into COSMO CLM

- COSMO5.0_CLM6
- CORDEX-EU 0.44° dt=300 s, ERAInterim driven
- Tegen Aerosol Climatology
- 1979-1985 (1981-1985 for evaluation)
- 10 soil layers, down to 11.5 m, 9 active layers (larger dynamical range)

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  Decharme et al. (2006) (Jürgen Helmert), only in modified TERRA_ML

$$K_0(kso) = K_{0,default} \cdot \exp\left(-2.0 \cdot (z(kso) - rootdp)\right)$$

rootdp: root depth

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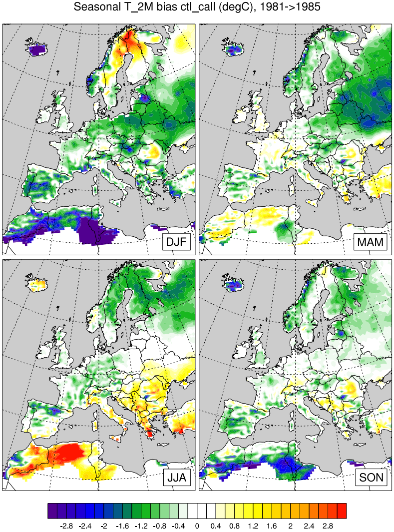
  rootdp: root depth
- New bare soil evaporation (itype_evsl=4) (Jan-Peter Schulz)

7-year simulation @50 km, sim-EOBS

DEFAULT (callibrated) MODIFIED (not callibrated)



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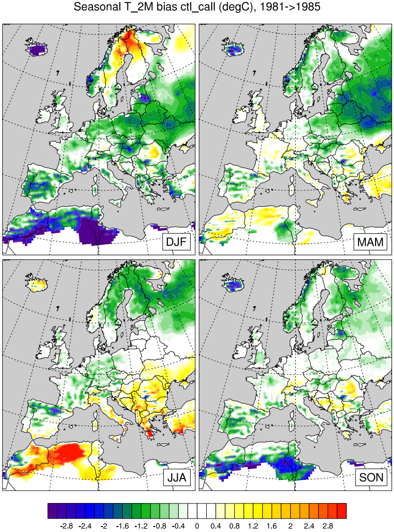

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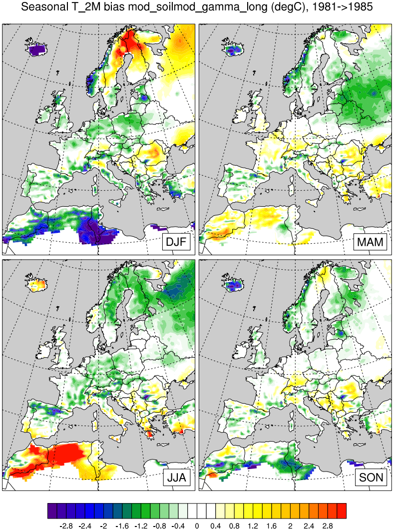

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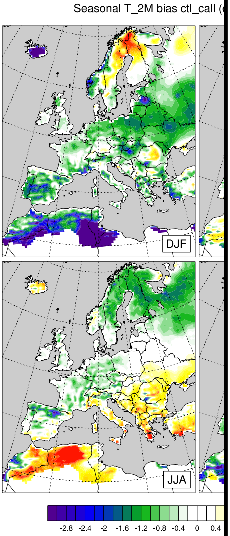
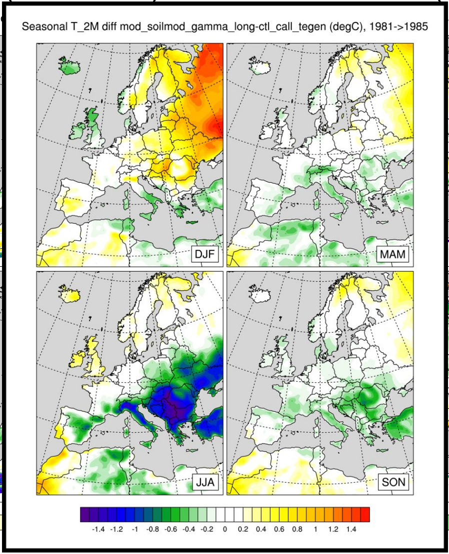
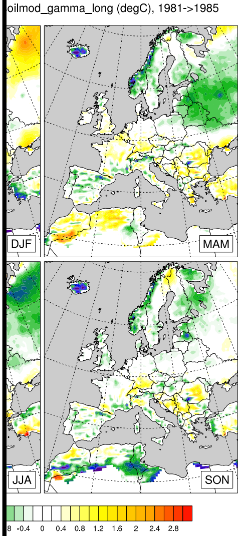


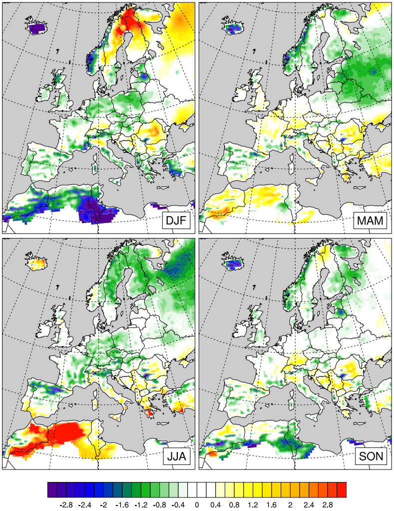




7-year simulation ⟶ 29-year simulation @50 km

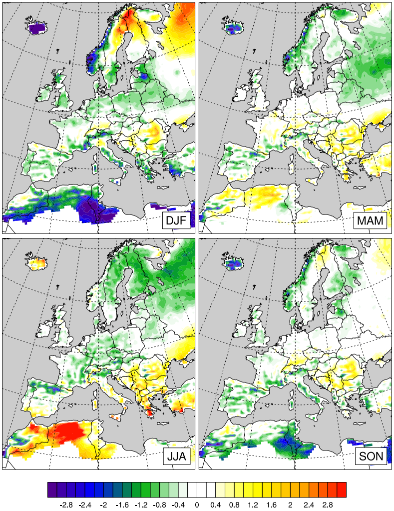
MODIFIED (not callibrated)

Seasonal T_2M bias mod_soilmod_gamma_long (degC), 1981->1985

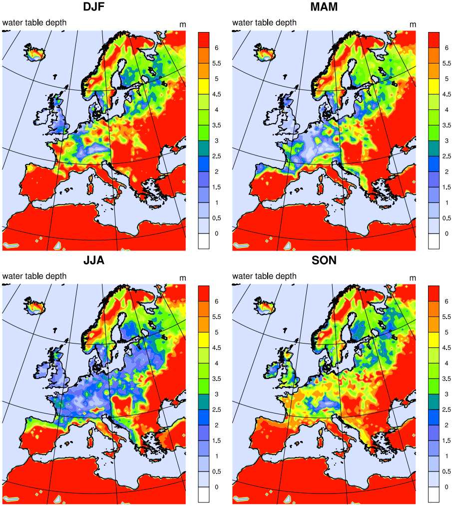


MODIFIED (not callibrated)

Seasonal T_2M bias mod_soilmod_gamma_long (degC), 1981->2007



Water-table depth



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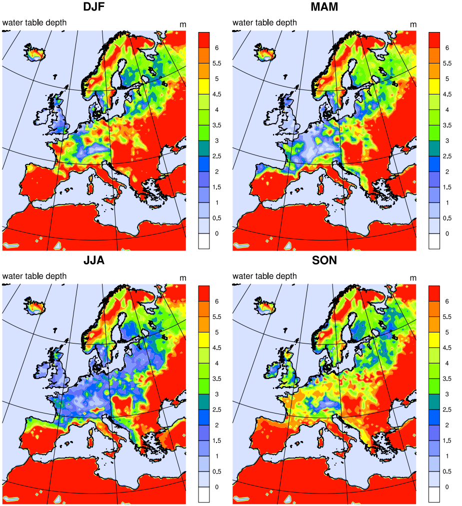
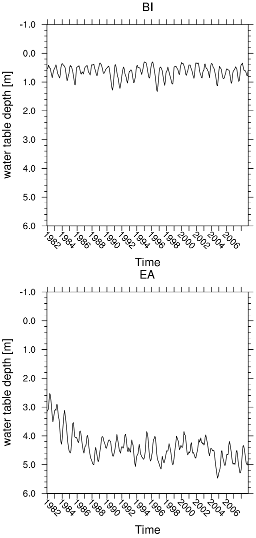


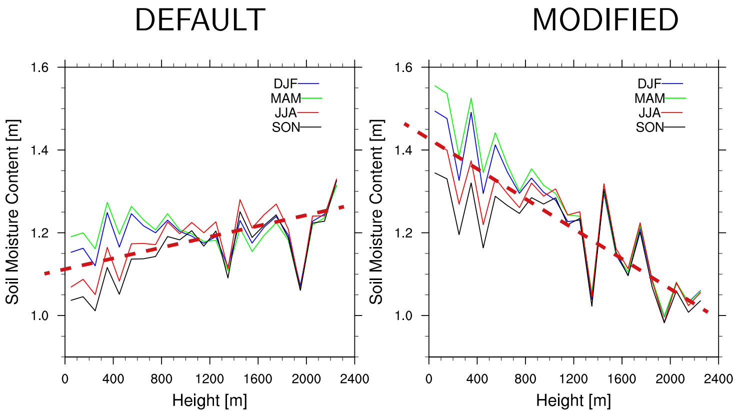


British Isles

Eastern Europe

Elevation-dependence of soil water content

Soil water content binned by elevation of terrain; Alpine (AL) region

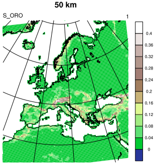


Soil-water content increases with height in the default version, whereas it decreases in the modified formulation

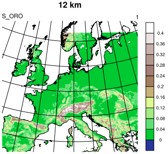
Resolution, Scale-Dependence

Slope parameter S_{oro} that determines ground water runoff

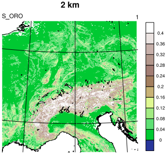
29-year simulation
@50 km
↓



↓
1-year simulation
@12 km
↓



↓
3-month simulation
@2 km

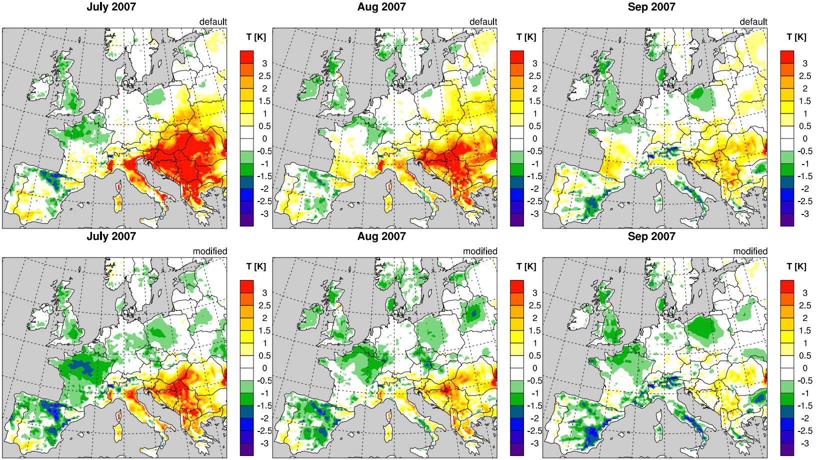


12 km simulation, Oct 2006-Oct 2007, ERAI-driven

T_{2m} bias (EOBS)

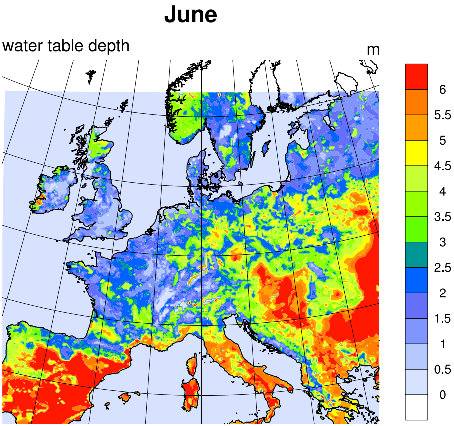
OLD

NEW



Water-table depth

12 km simulation



Water-table depth

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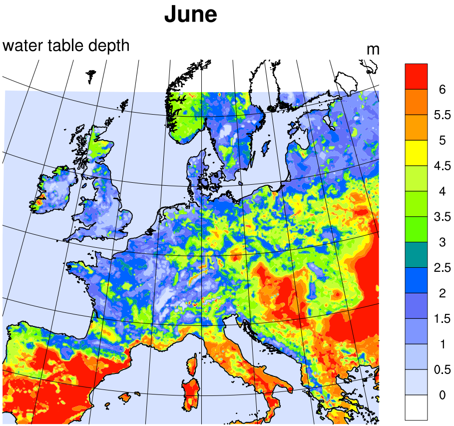
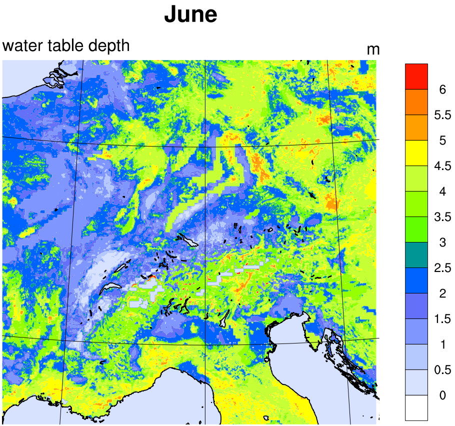
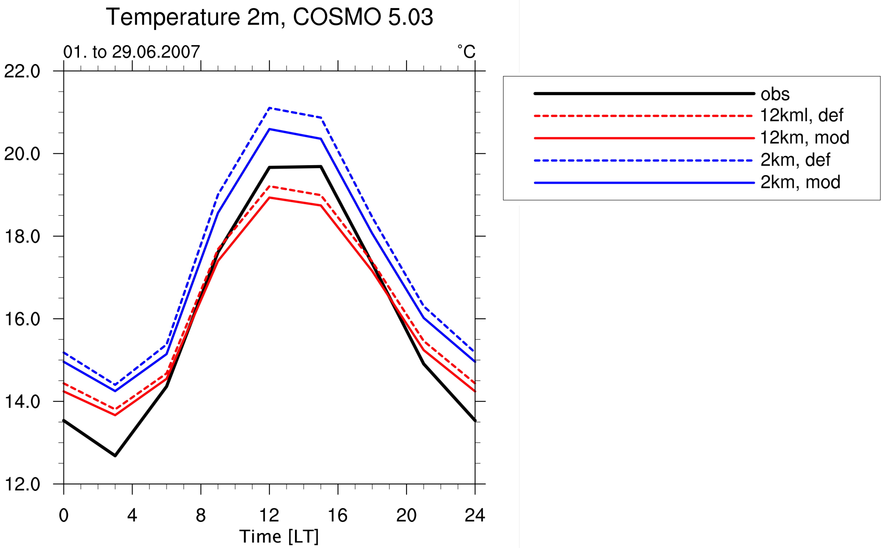


2 km simulation



Comparison to 24 stations over Switzerland



Conclusions

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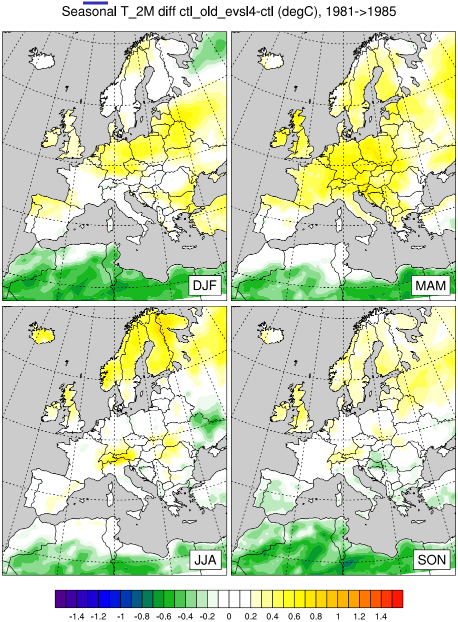
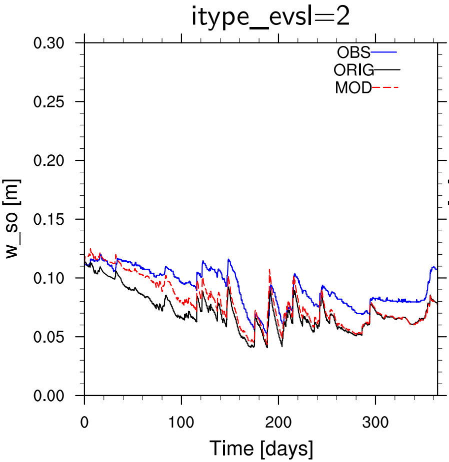
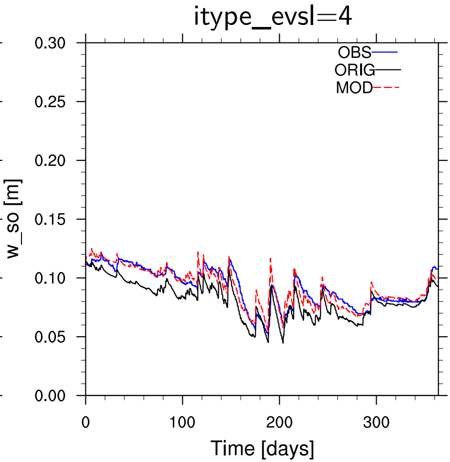
- Both idealized and climate simulations show improvements
- CCLM in combination with soil model not callibrated yet
- validation (Lindenberg, Fauga Mauzac)
- Simulations Δx=50 km $\Rightarrow$ Δx=12 km $\Rightarrow$ Δx=2 km show little impact of the scale of S_{oro}

EVSL_4

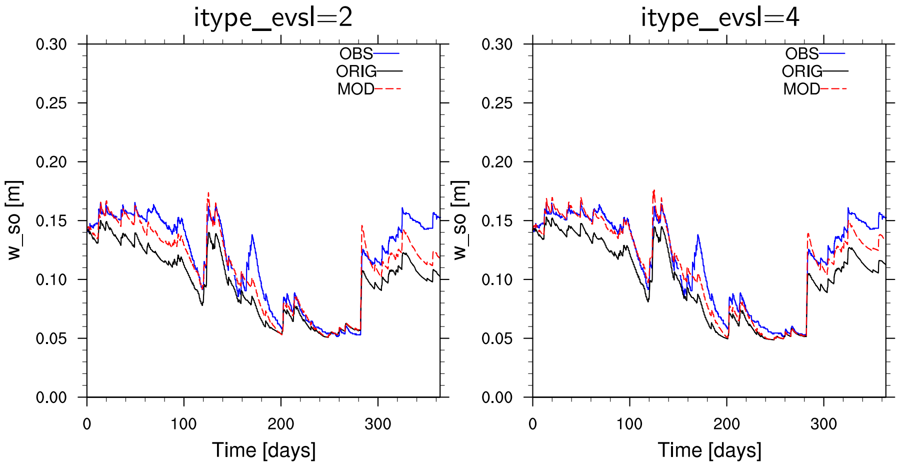

Seasonal T_2M diff ctl_old_evsl4-ctl (degC), 1981->1985
DJF
MAM
JJA
SON
-1.4 -1.2 -1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1 1.2 1.4

Validation, Lindenberg (Berlin), 2014



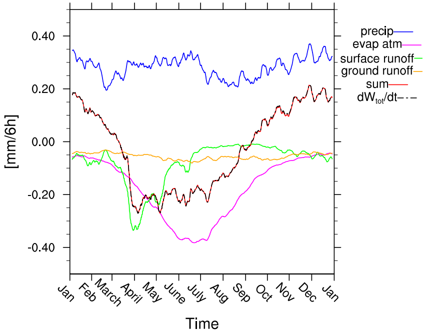


Validation, Fauga Mauzac (Toulouse, Southern France), 2010

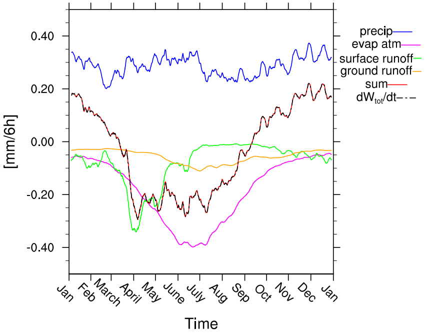


7-year simulation @50 km, budget

DEFAULT

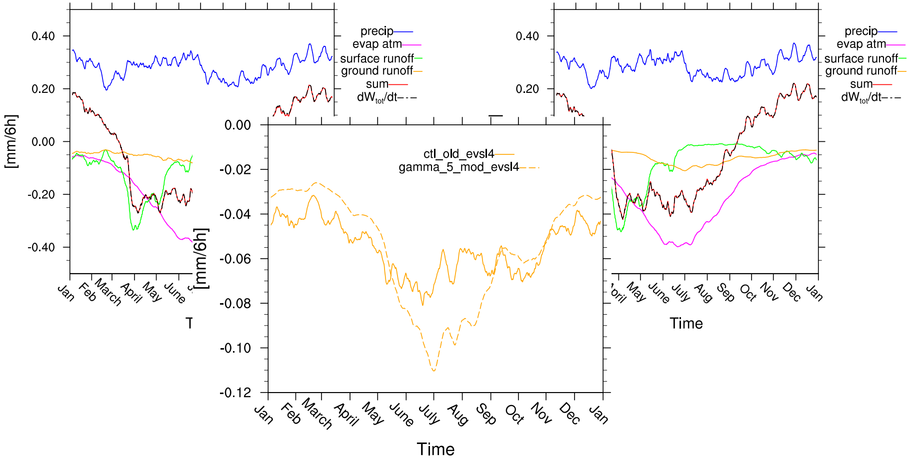


MODIFIED



7-year simulation @50 km, budget

DEFAULT MODIFIED



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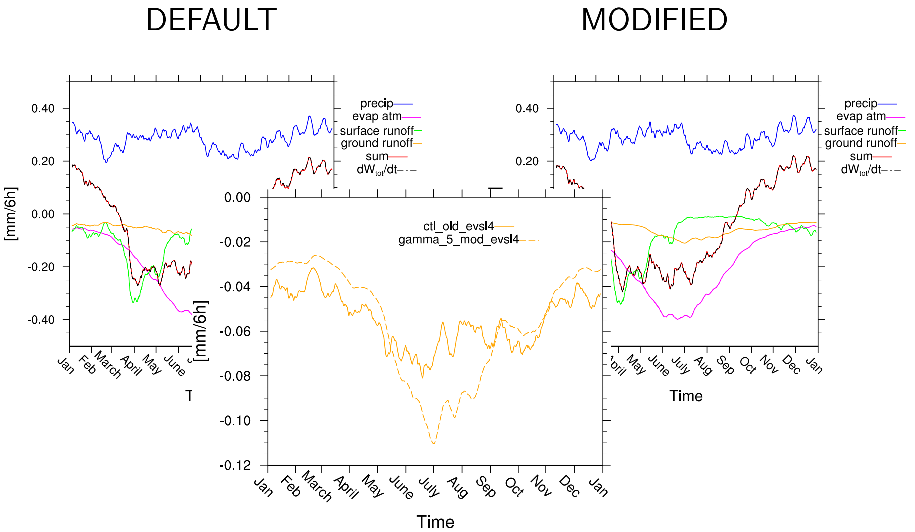
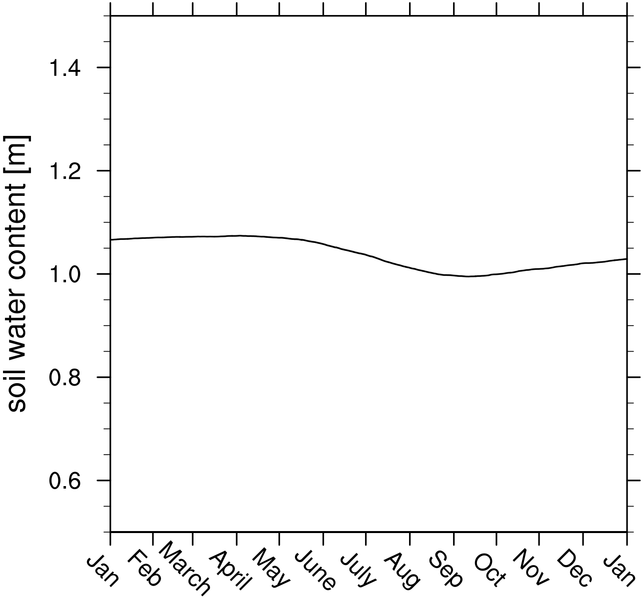


soil-water budget closes well for both model versions

annual cycle of ground runoff

Water content

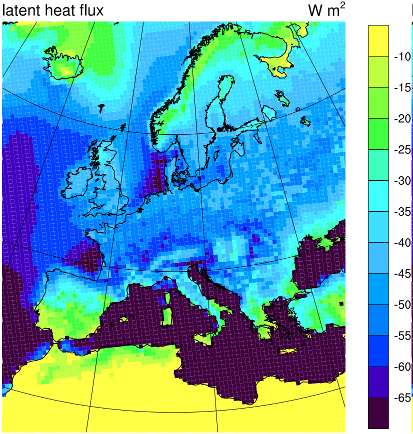


Annual cycle

Latent heat flux JJA

DEFAULT

JJA



MODIFIED

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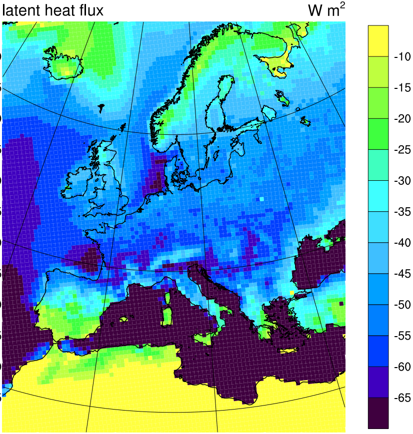
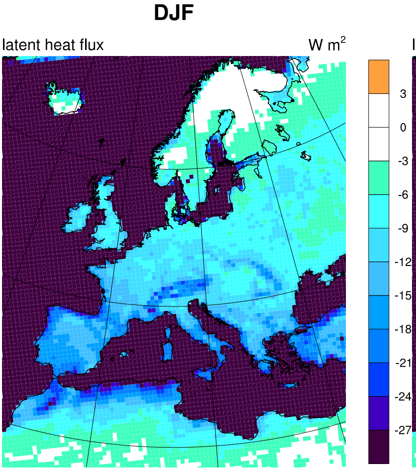
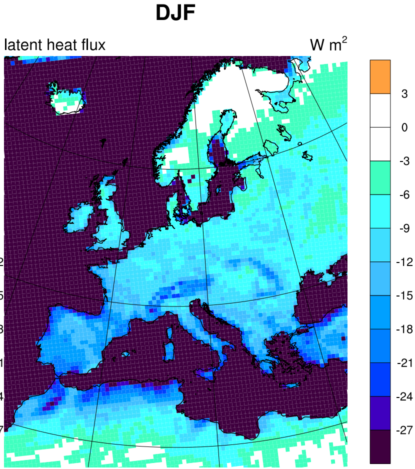


Latent heat flux DJF

DEFAULT



MODIFIED



Parameters K and D