

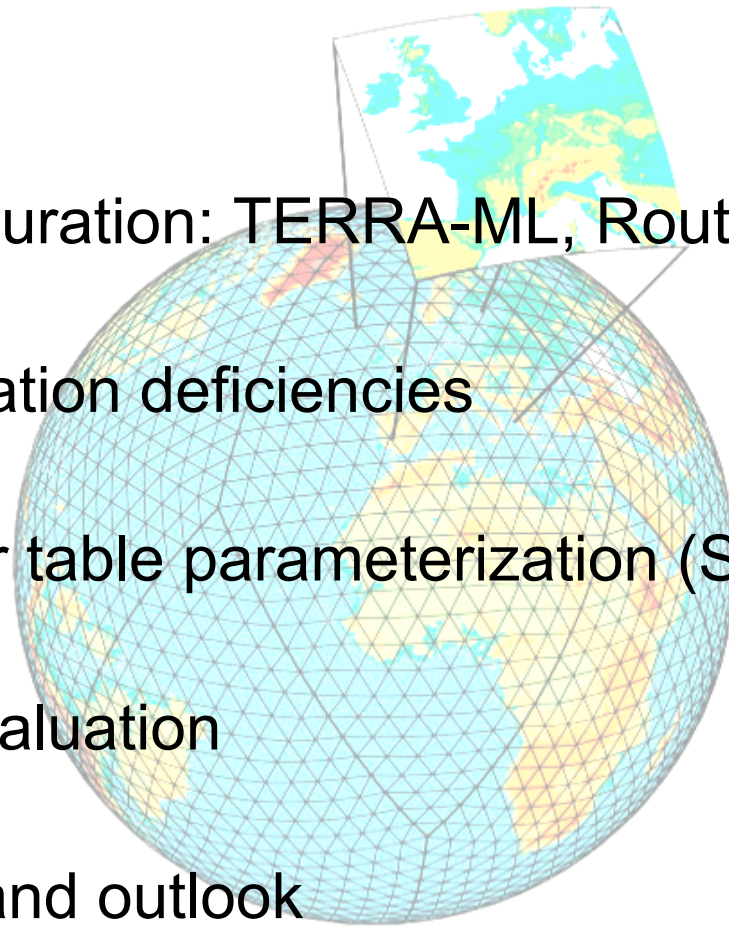
Validation of TERRA-ML with discharge measurements

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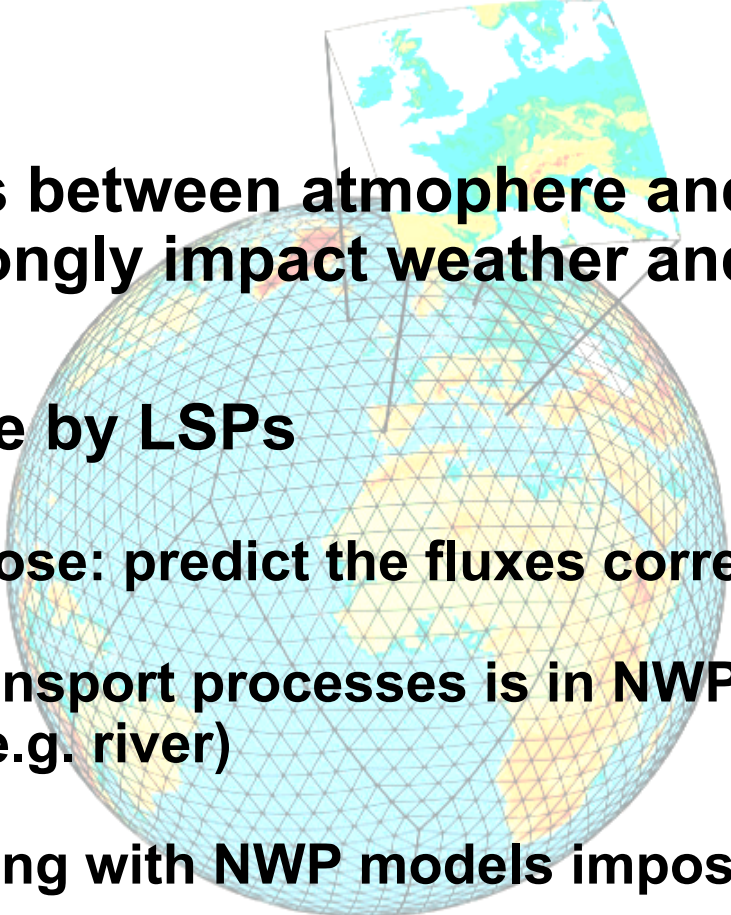
1 University of Bonn, 2 University of Hohenheim, 3 University of Hamburg,

Langen 2008

- Introduction
- Model configuration: TERRA-ML, Routing-Scheme
- Parameterization deficiencies
- Groundwater table parameterization (SIMTOP)
- Statistical evaluation
- Conclusion and outlook

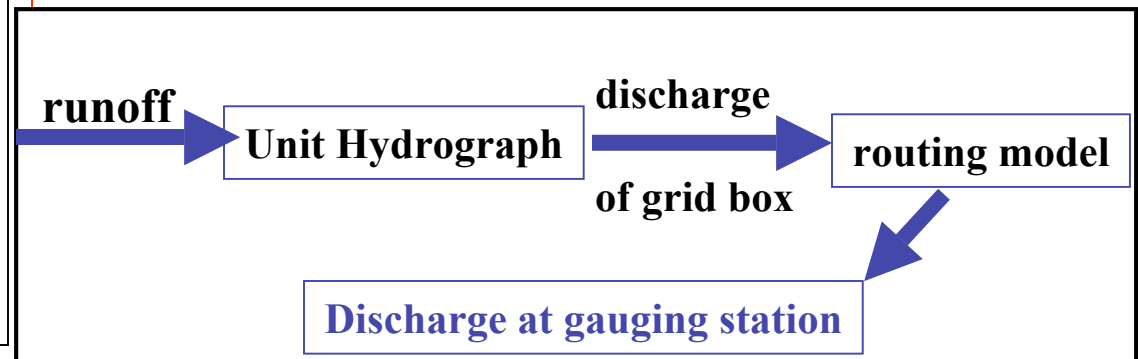
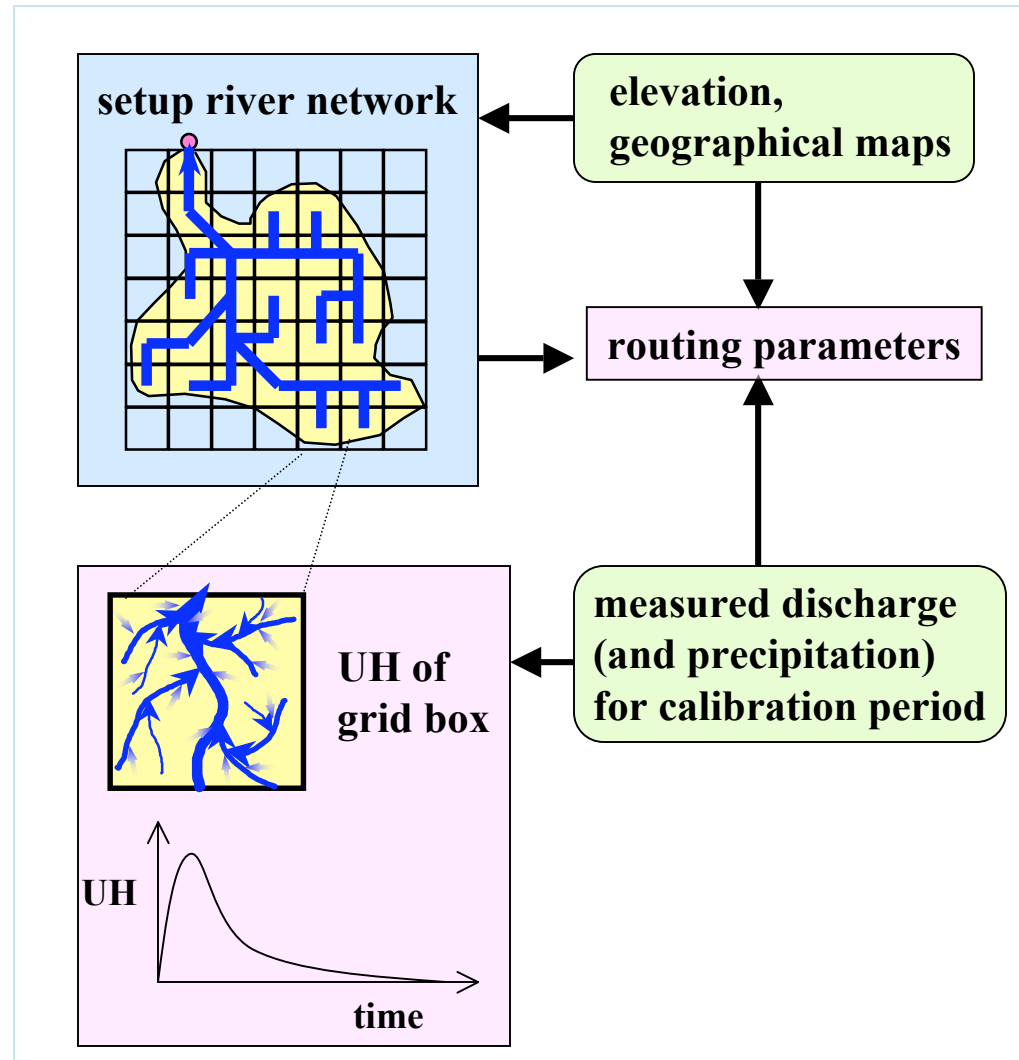
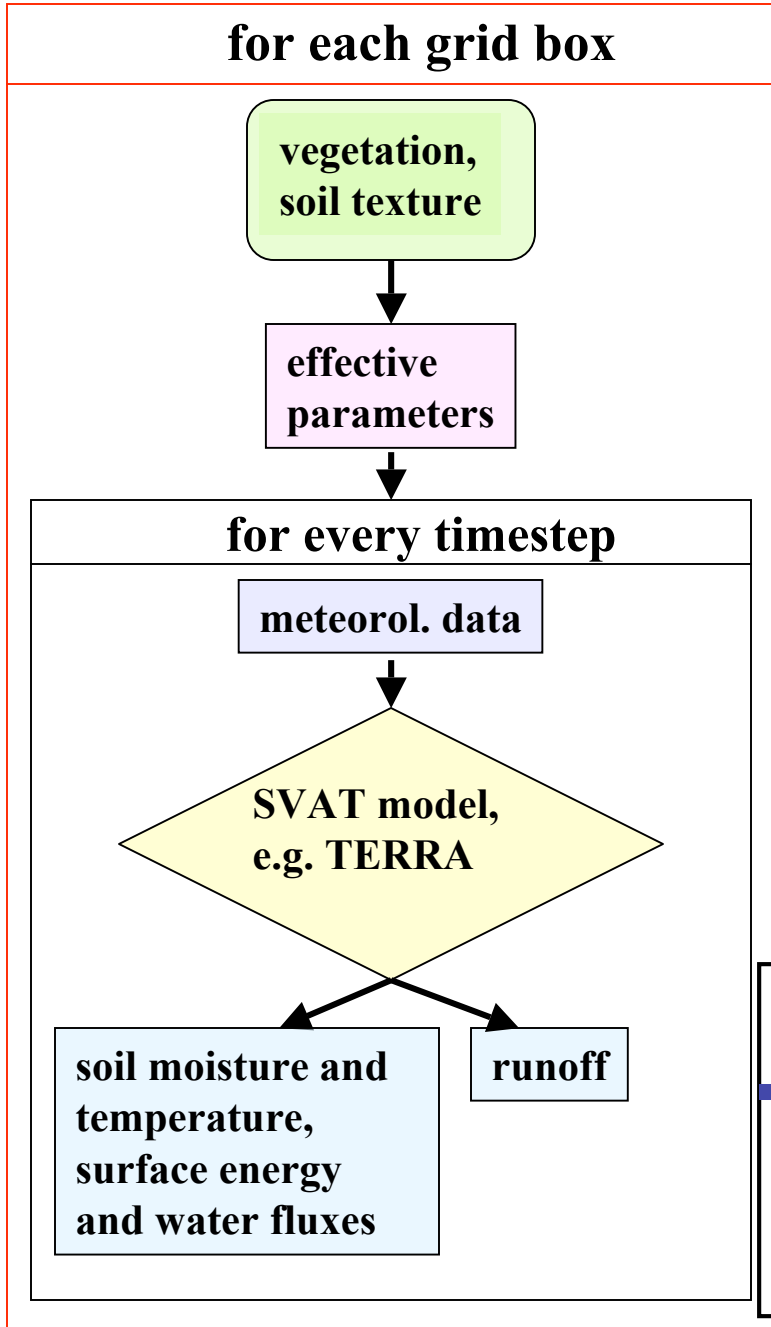


Introduction:

- **interactions between atmosphere and land surface strongly impact weather and climate**
 - **the interface by LSPs**
 - **primary purpose: predict the fluxes correctly**
 - **horizontal transport processes is in NWP insufficient considered (e.g. river)**
 - **flood forecasting with NWP models impossible**
- 
- A globe with a grid overlay, showing a zoomed-in view of Europe and the Mediterranean region. The globe is rendered in a light blue and yellow color scheme, with a grid of lines representing latitude and longitude. A rectangular inset map is positioned above the globe, showing a more detailed view of the European continent and the surrounding Mediterranean Sea, with a color scale ranging from blue to red, indicating different levels of intensity or flux.

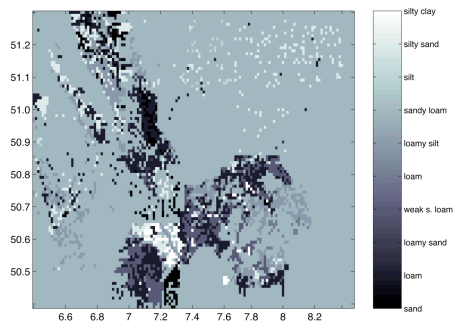
Model configuration:

for each grid box

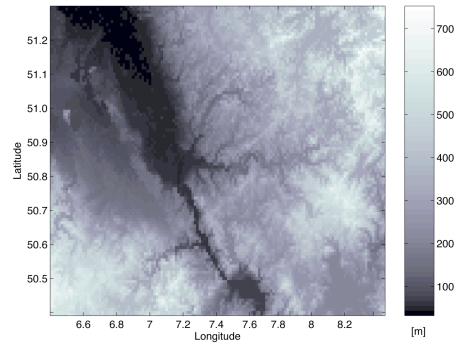


Model configuration - Terra Stand Alone

soil fields:



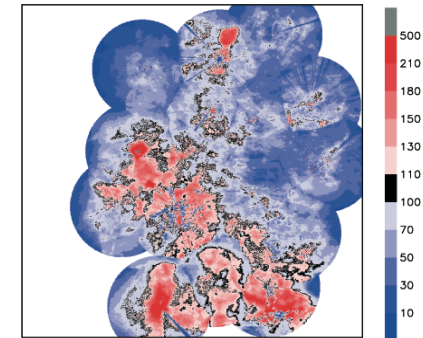
• soil data BK 50



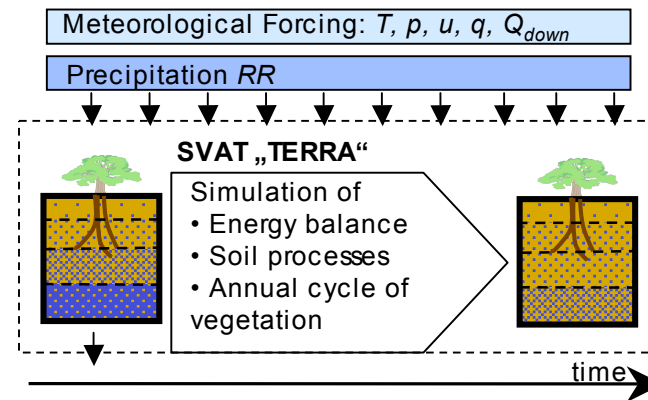
• topography (NASA-SRTM)

• vegetation (CORINE)

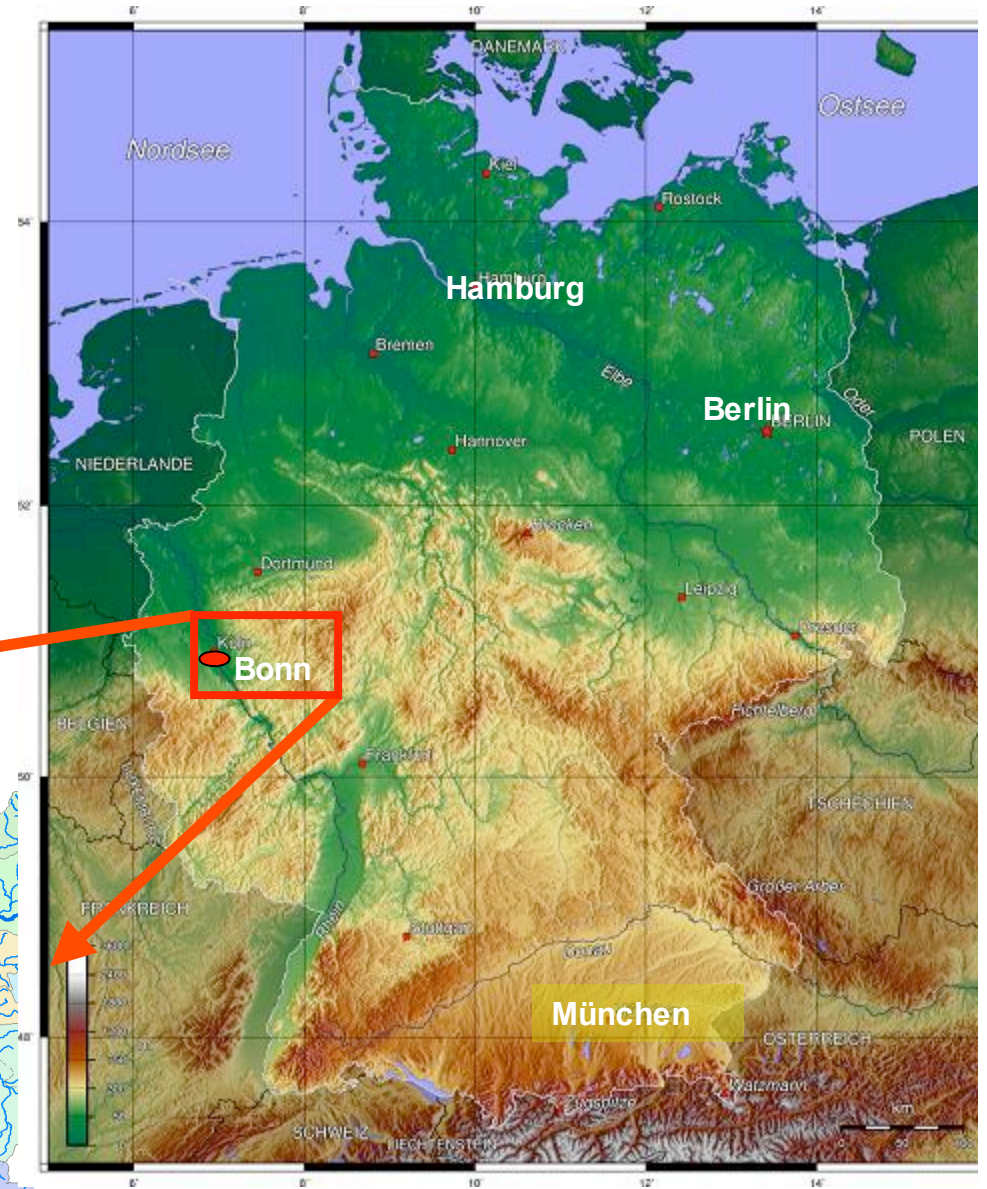
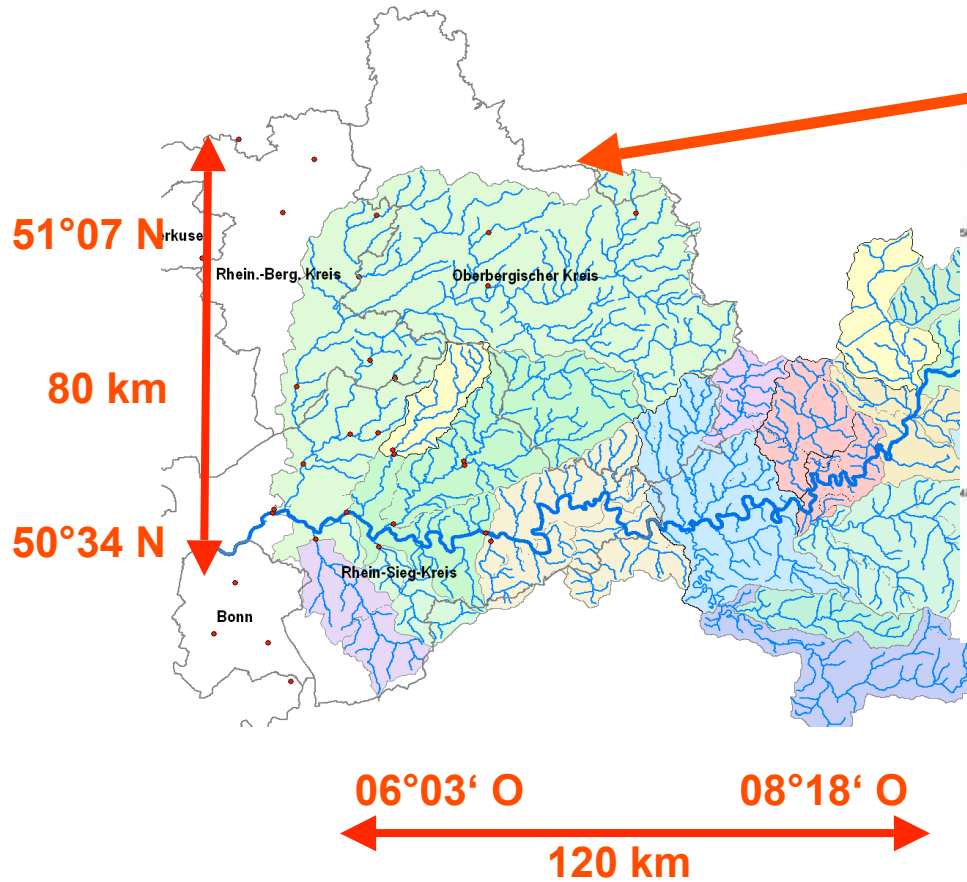
meteorological forcing:



• RADOLAN



The Sieg and Agger catchment



Soil water parameterization: vertical watertransport

The flux of soil moisture in unsaturated soil is the sum of drainage and diffusion and can be written as one dimensional Darcy equation:

$$F_{\eta} = K(\eta) + D(\eta) \frac{\partial \eta}{\partial z}$$

hydraulic conductivity and hydraulic diffusivity depend both on the soil moisture and the textures. Both function are parameterised by the exponential laws (Rijtima, 1969):

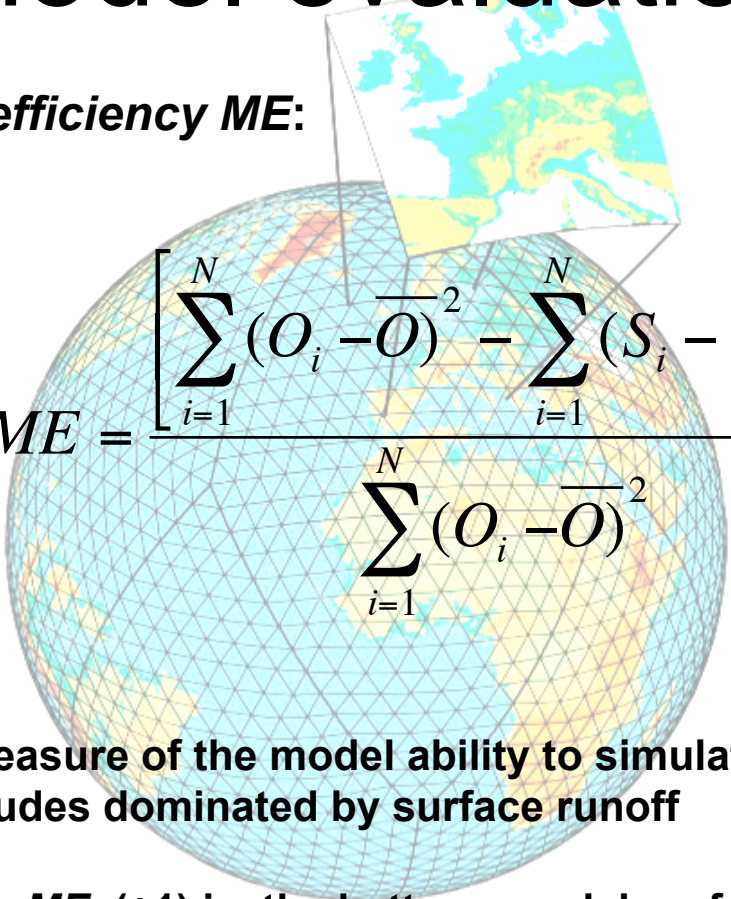
$$K(\eta) = K_0 \exp\left(K_1 \frac{\eta_{PV} - \eta}{\eta_{PV} - \eta_{ADP}}\right) \quad D(\eta) = D_0 \exp\left(D_1 \frac{\eta_{PV} - \eta}{\eta_{PV} - \eta_{ADP}}\right)$$

New parameterisation in Terra-Stand-alone (Campbell 1974):

$$K(\eta) = K_0 \cdot \left(\frac{\eta}{\eta_{PV}}\right)^c \quad D(\eta) = -b \cdot \psi_{ae} \cdot K_0 \cdot \eta_{PV}^{-b-3} \cdot \eta^{b+2}$$

Model evaluation

- *model efficiency ME*:

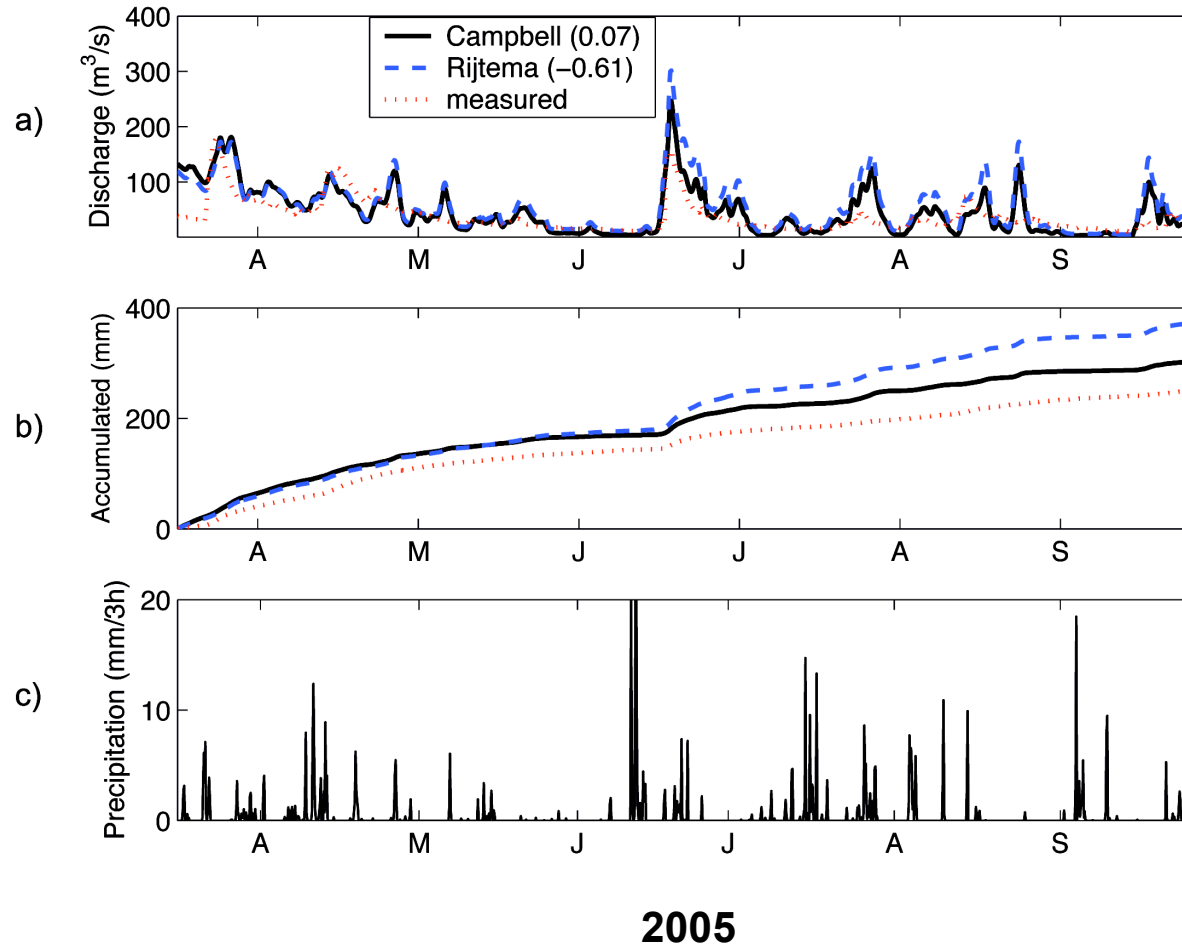

$$ME = \frac{\left[\sum_{i=1}^N (O_i - \bar{O})^2 - \sum_{i=1}^N (S_i - O_i)^2 \right]}{\sum_{i=1}^N (O_i - \bar{O})^2}$$

***ME* is a measure of the model ability to simulate the runoff amplitudes dominated by surface runoff**

The higher *ME* (+1) is, the better a model performs

Soil water parameterization: vertical watertransport

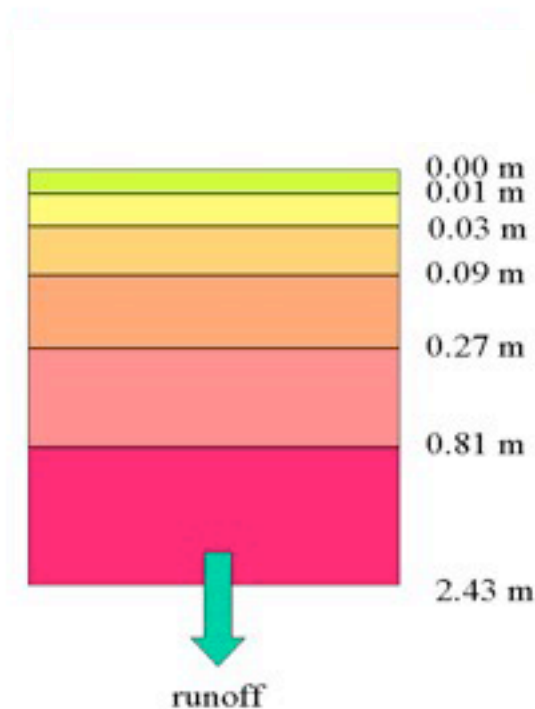
Precipitation: RADOLAN RW



station: Menden/Sieg

Ground water table parameterization

Lower boundary condition: drying out Terra-stand-alone



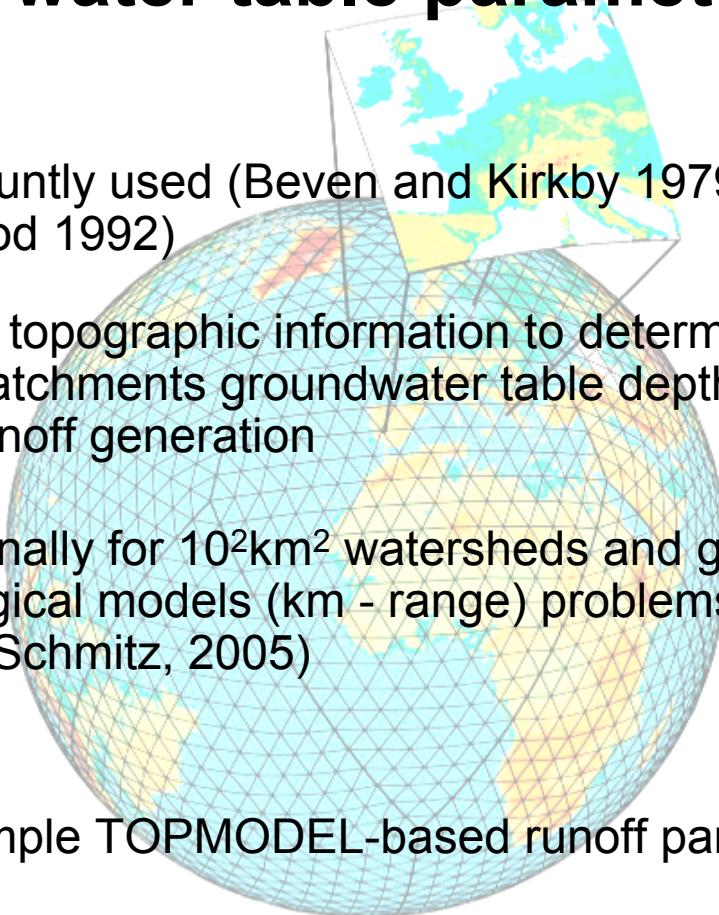
ground water can drain from lowest layer -
flux due to diffusion is neglected

ground water cannot wetten the soil by capillary
rise from below

TERRA tend to dry soil conditions, especially in
summer

the idea: replace **lower boundary condition** by
simulation of a variable ground water table

Ground water table parameterization

- 
- **TOPMODEL** - frequently used (Beven and Kirkby 1979), e.g. TOPLATS (Famigletti and Wood 1992)
 - TOPMODEL - uses topographic information to determine the statistical distribution of the catchments groundwater table depth and the impact this heterogeneity on runoff generation
 - **Disadvantage** - originally for 10^2km^2 watersheds and grid cells in range of meters - meteorological models (km - range) problems by calculation of the topographic index (Schmitz, 2005)
 - **Terra - approach:**
 - Niu et al. 2005 - Simple TOPMODEL-based runoff parametrization (SIMTOP)
 - Stieglitz et al. 1997 - coupled the analytical part of TOPMODEL to a SVAT-module with the objective to minimize computational costs

Ground water table parametrization

- the **SIMTOP** approach simplifies the subsurface runoff:

$$R_{sb} = R_{Sb \max} e^{-f\bar{z}}$$

$R_{Sb \max}$ - max. subsurface runoff $\bar{z} = 0$
 f - decay factor

- the **TOPMODEL** approach determine the subsurface runoff:

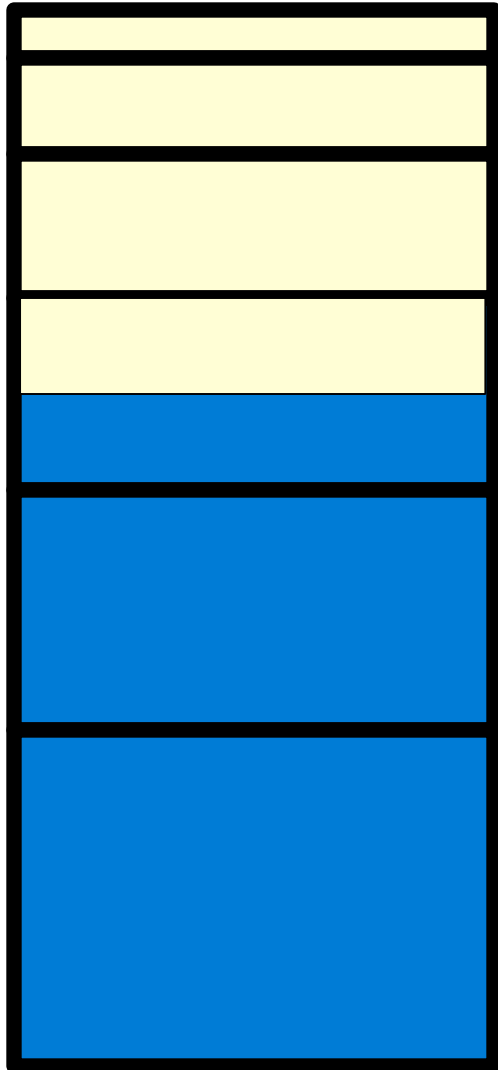
$$R_{sb} = \frac{K_{sat}(0)}{f} e^{-\lambda_m} e^{-f\bar{z}}$$

λ_m - mean topographic index
 K_{sat} - saturated hydraulic conductivity
 f - decay factor

To find: Groundwater tabel depth \bar{z}

Ground water table parameterization

$$i = 1 \dots n$$



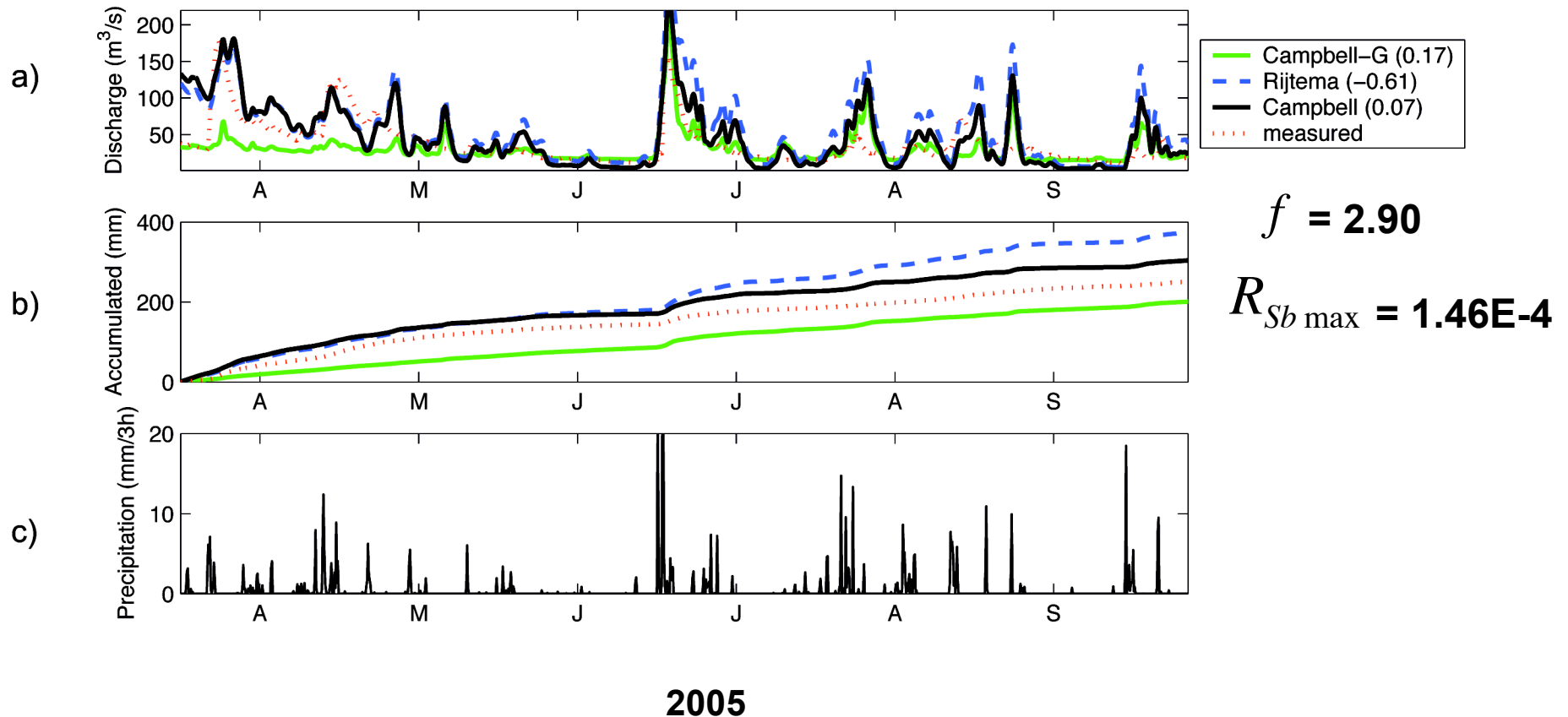
the **groundwater table** is located within the first **unsaturated layer** i :

$$\bar{z} = zb_i \quad , \quad \eta_i \leq 0.7\eta_{FC}$$

$$\bar{z} = zb_i - \left(\frac{\eta_i - 0.7\eta_{FC}}{\eta_{PV} - 0.7\eta_{FC}} \right) \Delta z_i \quad , \quad \eta_i > 0.7\eta_{FC}$$

Ground water table parameterization

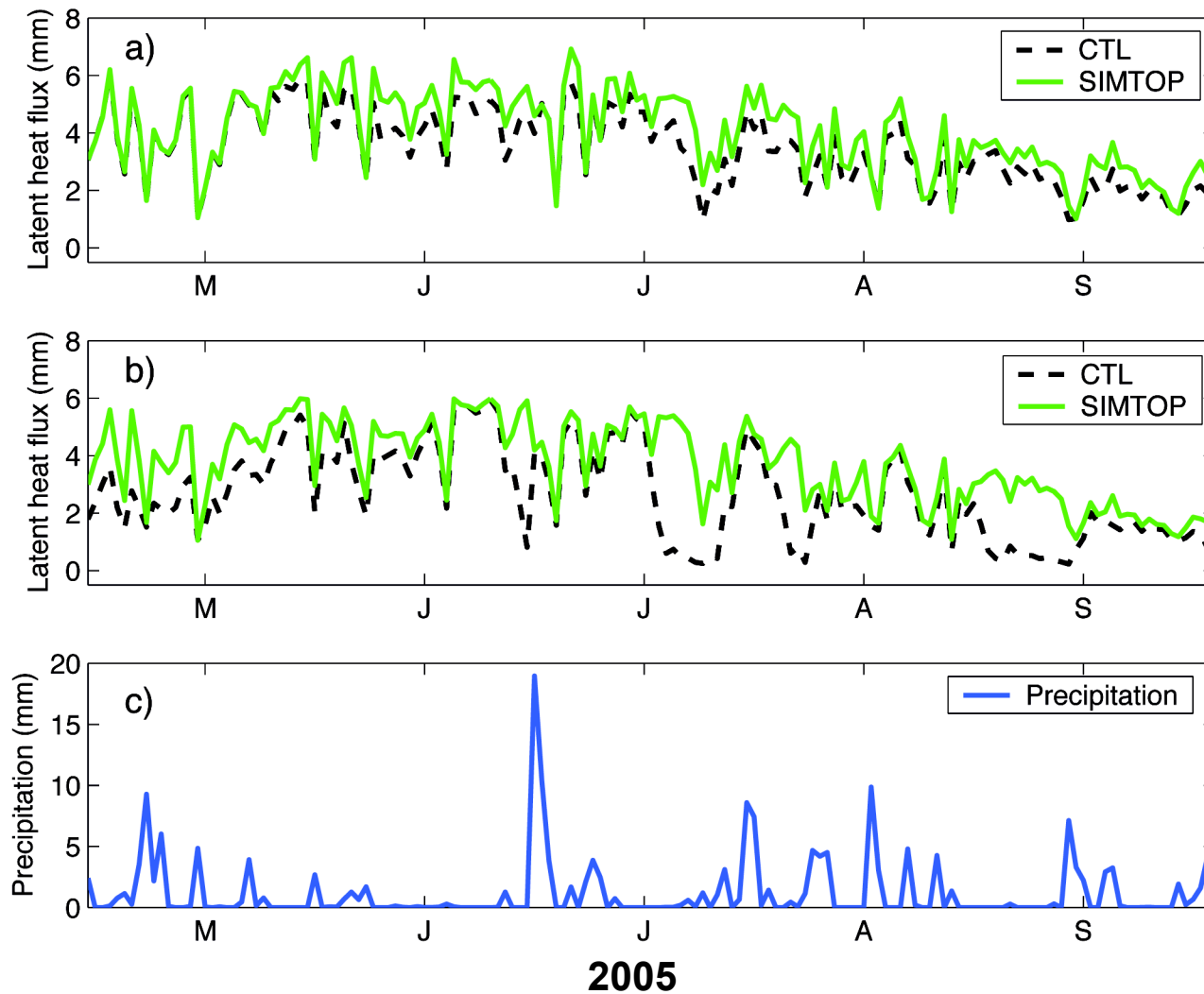
Precipitation: RADOLAN RW



station: Menden/Sieg

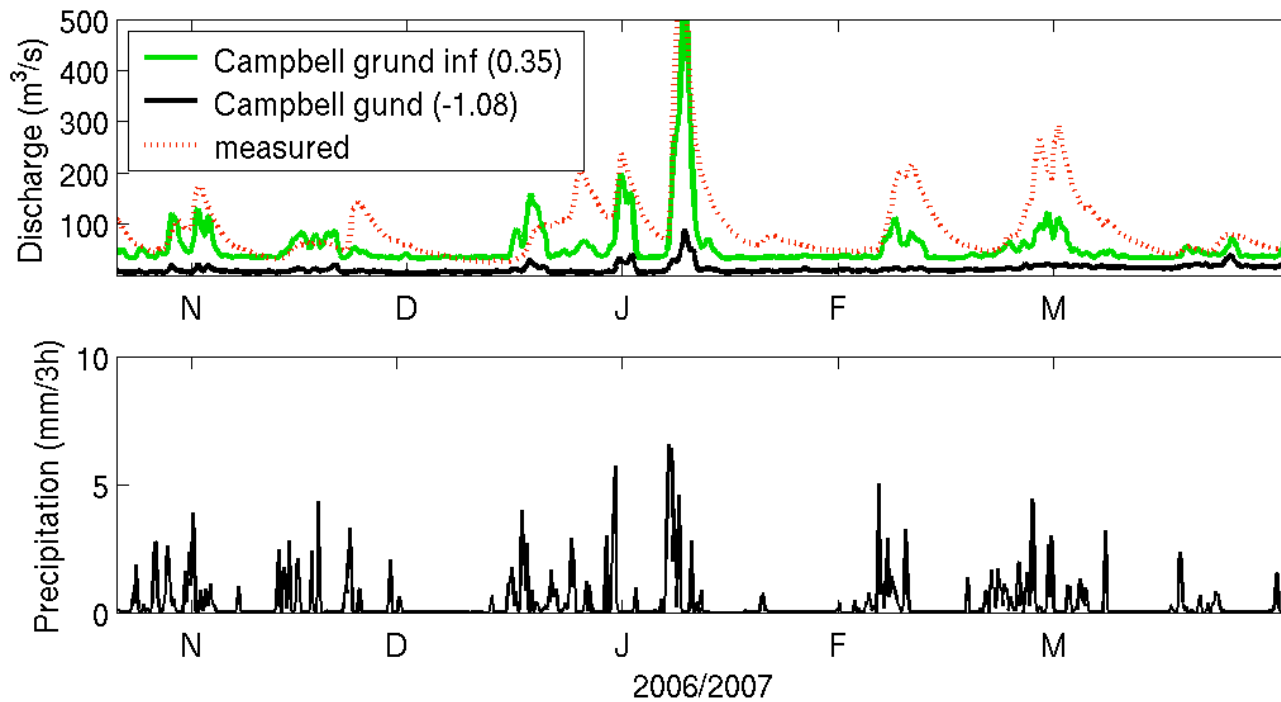
Ground water table parameterization

Latent Heat Flux (LHFL) calculated by TERRA-ML



Ground water table parameterization

Precipitation: RADOLAN RW



$$R_{Sb \max} = 1.46\text{E-}4$$

$$R_{Sb \max} = 4.46\text{E-}4$$

$$f = 3.26$$

$$f = 2.90$$

infiltration parameter
????

Ground water table parameterization

The infiltration in TERRA-ML given by a simplified Holtan-equation::

$$I'_{\max} = 0$$

$$: T_{scf} \leq T_0$$

$$I'_{\max} = (f_r S_{oro} \left[\text{Max}(0.5; f_{p \ln t}) I_{K1} (\eta_{pv} - \eta_l) / \eta_{pv} + I_{K2} \right])$$

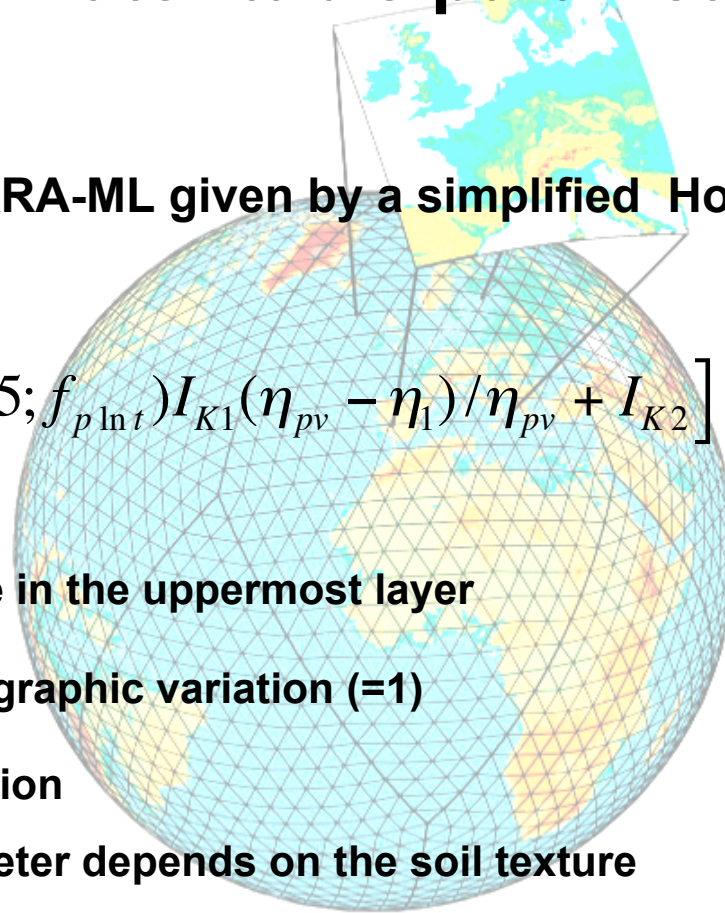
$$: T_{scf} > T_0$$

f_r Fraction of soil ice in the uppermost layer

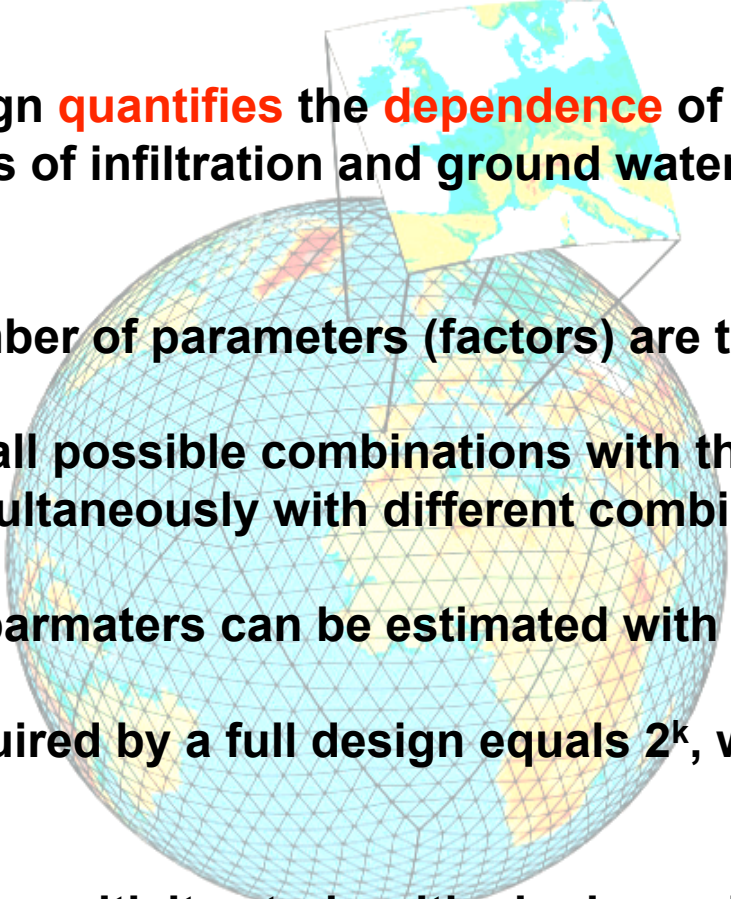
S_{oro} Subgrid scale orographic variation (=1)

I_{K1} Maximum infiltration

I_{K2} Infiltration parameter depends on the soil texture



Two-level factorial design

- 
- two level factorial design **quantifies** the **dependence** of discharge on the input parameters of infiltration and ground water table parameterization (Box et al. 1978)
 - two levels for each number of parameters (factors) are taken (low and high)
 - the runs are done with all possible combinations with the assumption that the parameters change simultaneously with different combinations
 - the **interactions** of the parameters can be estimated with a high precision
 - the number of runs required by a full design equals 2^k , where k equals number of factors
 - **advantage** to a simple sensitivity study with single model run estimate only the effect of single variable
 - **computational efficient** compared to more complexity experiments

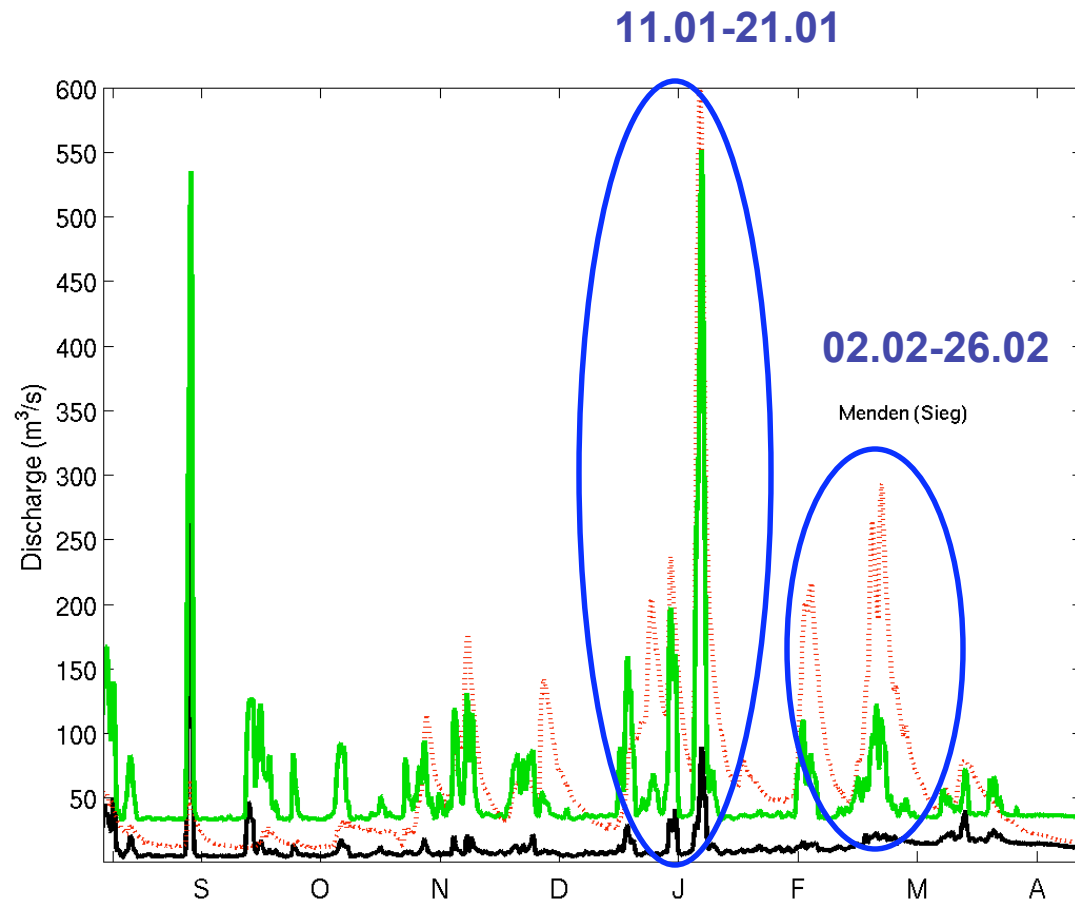
Two-level factorial design

Variable High + Median 0 Low -

| | | | |
|--------------|--------|-----|--------|
| wet | 100% | 60% | 20% |
| f | 3.56 | | 2.90 |
| $R_{sb,max}$ | 4.46+4 | | 0.46+4 |
| I_{K1} | 0.0036 | | 0.0004 |
| I_{K2} | 180% | | 20% |

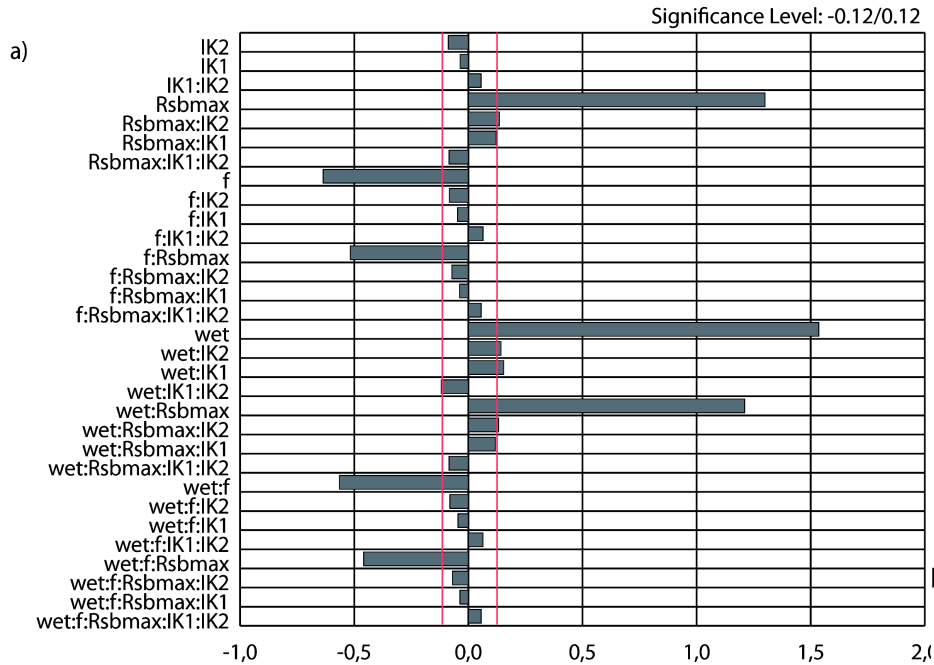
| run | Initial | f | $R_{sb,max}$ | I_{k1} | I_{K2} |
|-----|---------|---|--------------|----------|----------|
| 1 | - | - | - | - | - |
| 2 | - | - | - | - | + |
| 3 | - | - | - | + | - |
| 4 | - | - | - | + | + |
| 5 | - | - | + | - | - |
| 6 | - | - | + | - | + |
| 7 | - | - | + | + | - |
| 8 | - | - | + | + | + |
| 9 | - | + | - | - | - |
| 10 | - | + | - | - | + |
| 11 | - | + | - | + | - |
| 12 | - | + | - | + | + |
| 13 | - | + | + | - | - |
| 14 | - | + | + | - | + |
| 15 | - | + | + | + | - |
| 16 | - | + | + | + | + |
| 17 | + | - | - | - | - |
| 18 | + | - | - | - | + |
| 19 | + | - | - | + | - |
| 20 | + | - | - | + | + |
| 21 | + | - | + | - | - |
| 22 | + | - | + | - | + |
| 23 | + | - | + | + | - |
| 24 | + | - | + | + | + |
| 25 | + | + | - | - | - |
| 26 | + | + | - | - | + |
| 27 | + | + | - | + | - |
| 28 | + | + | - | + | + |
| 29 | + | + | + | - | - |
| 30 | + | + | + | - | + |
| 31 | + | + | + | + | - |
| 32 | + | + | + | + | + |
| 33 | 0 | - | - | - | - |
| 34 | 0 | - | - | - | + |
| 35 | 0 | - | - | + | - |
| 36 | 0 | - | - | + | + |
| 37 | 0 | - | + | - | - |
| 38 | 0 | - | + | - | + |
| 39 | 0 | - | + | + | - |
| 40 | 0 | - | + | + | + |
| 41 | 0 | + | - | - | - |
| 42 | 0 | + | - | - | + |
| 43 | 0 | + | - | + | - |
| 44 | 0 | + | - | + | + |
| 45 | 0 | + | + | - | - |
| 46 | 0 | + | + | - | + |
| 47 | 0 | + | + | + | - |
| 48 | 0 | + | + | + | + |

Two-level factorial design



2006/2007

Two-level factorial design



11.01.07 - 21.01.07 (-+)

Discharge Improvements:

Systematical setting of $R_{sb,max}$
from low to high

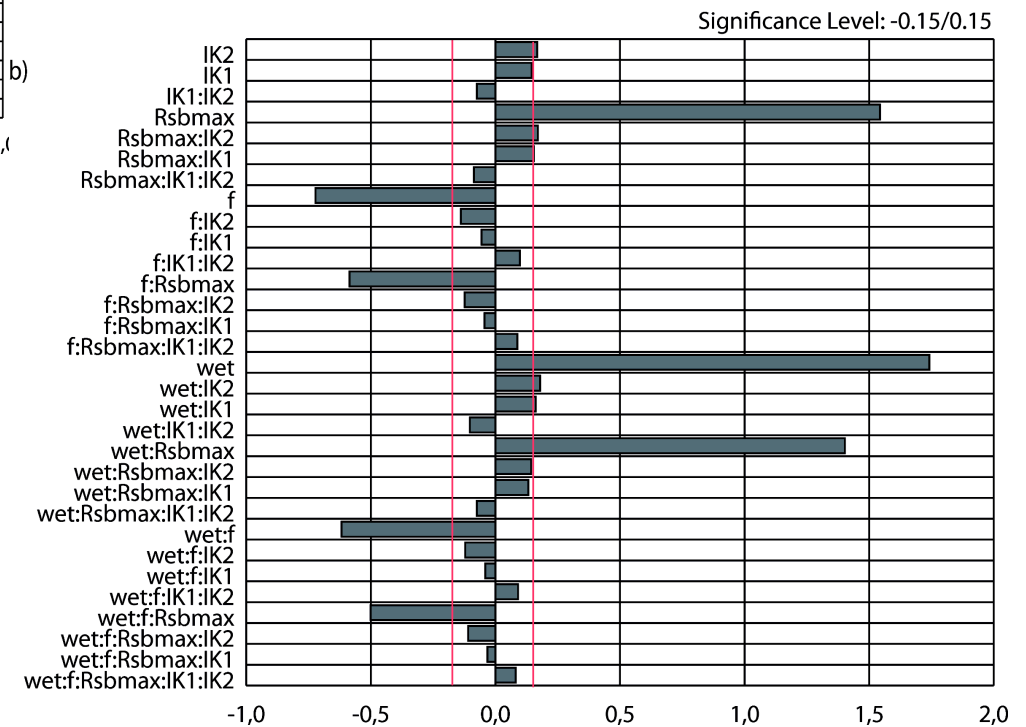
Systematical setting of *wet*
from low to high

Discharge deterioration:

Systematical setting of *f*
from low to high

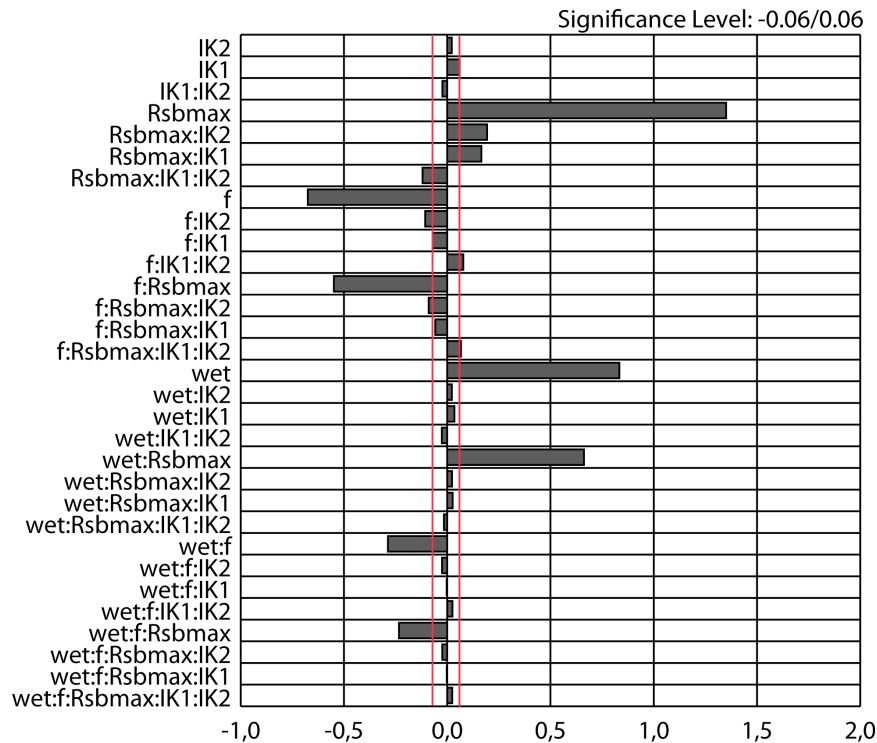
No significant
influence of infiltration rate

02.02.07 - 26.02.07 (-+)



Two-level factorial design

a)



Discharge deterioration:

**Systematical setting of f
from low to high**

**No significant
influence of infiltration rate**

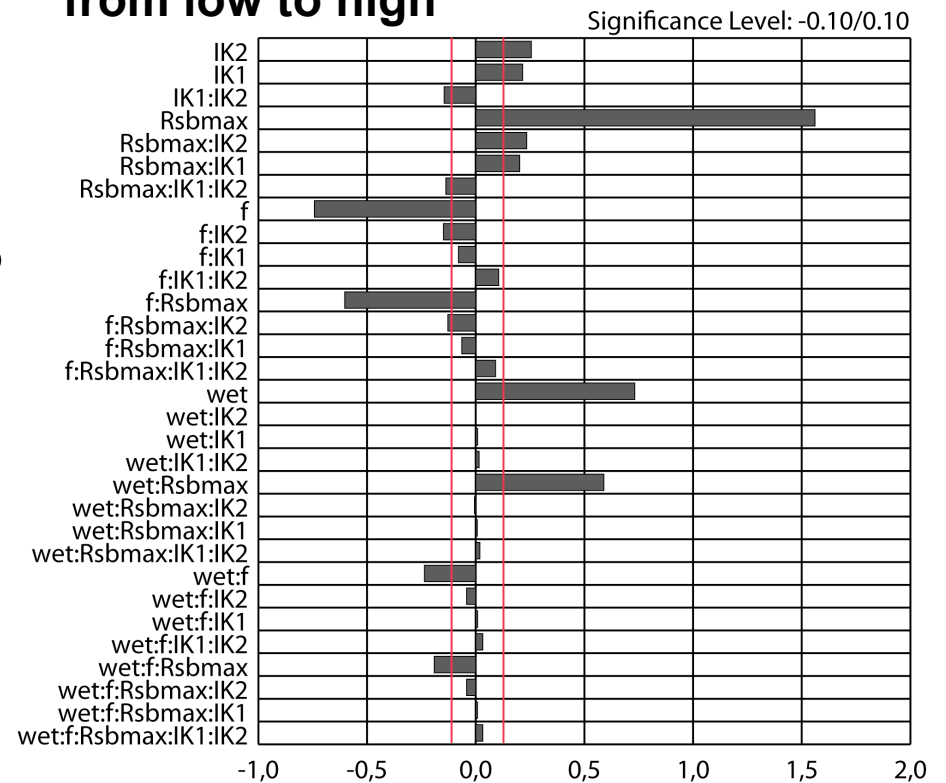
02.02.07 - 26.02.07 (0+)

11.01.07 - 21.01.07 (0+)

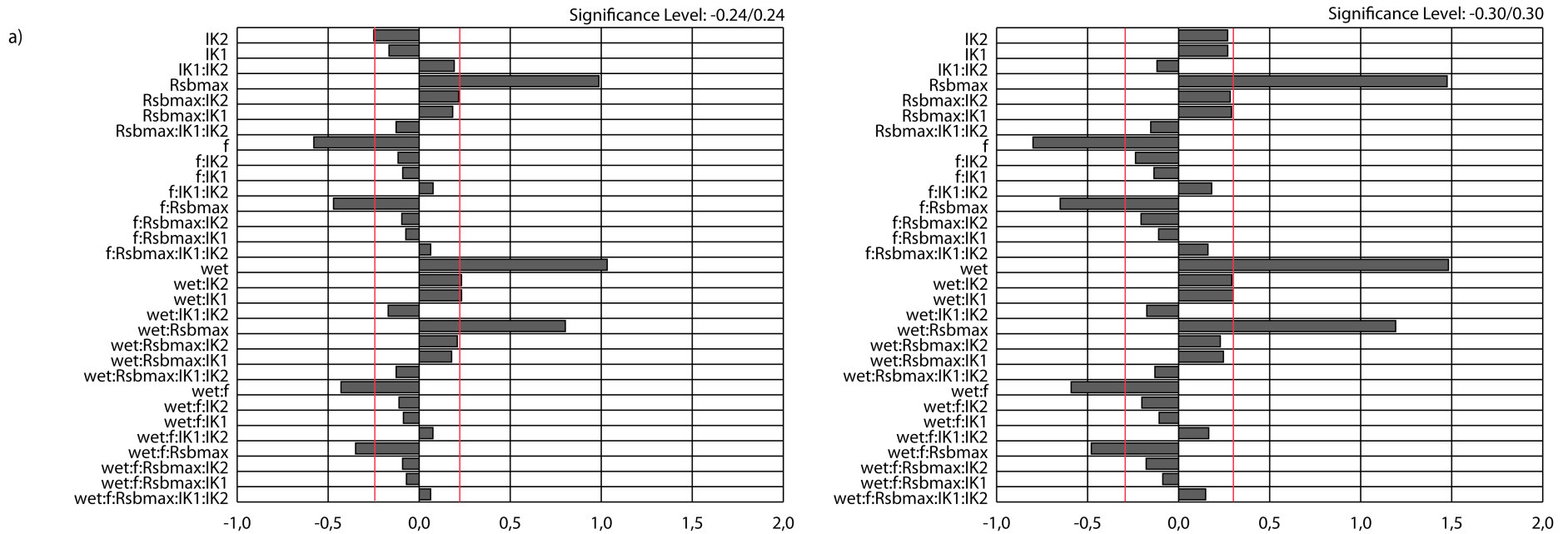
Discharge Improvements:

**Systematical setting of $R_{sb,max}$
from low to high**

**Systematical setting of $R_{sb,max}$
from low to high**



Two-level factorial design



Result of the study:

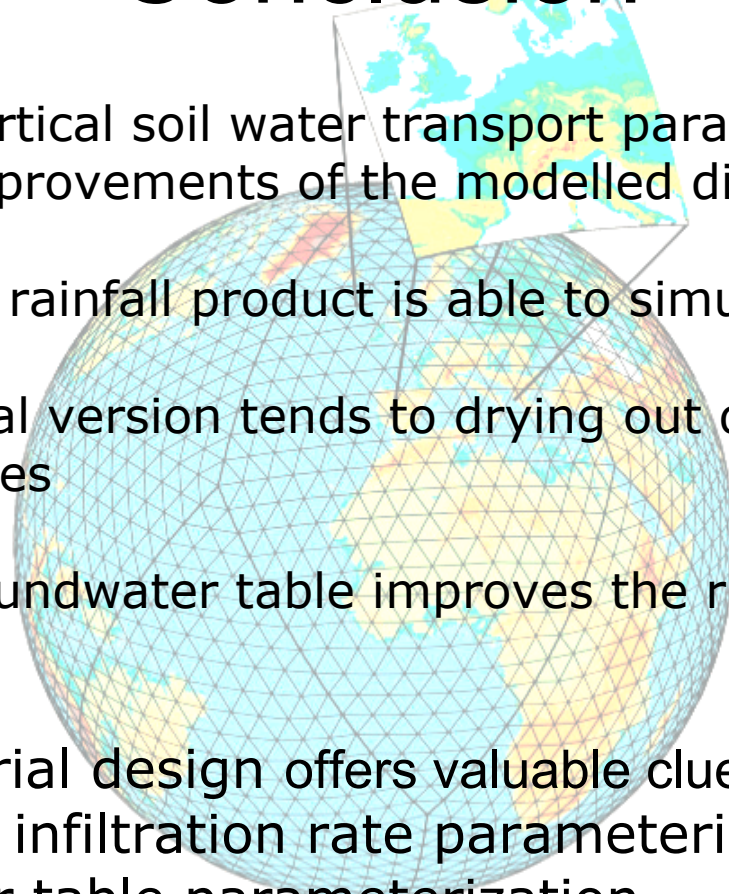
Groundwater table parameterization influences discharge simulation

Initial soil water conditions influences discharge simulation

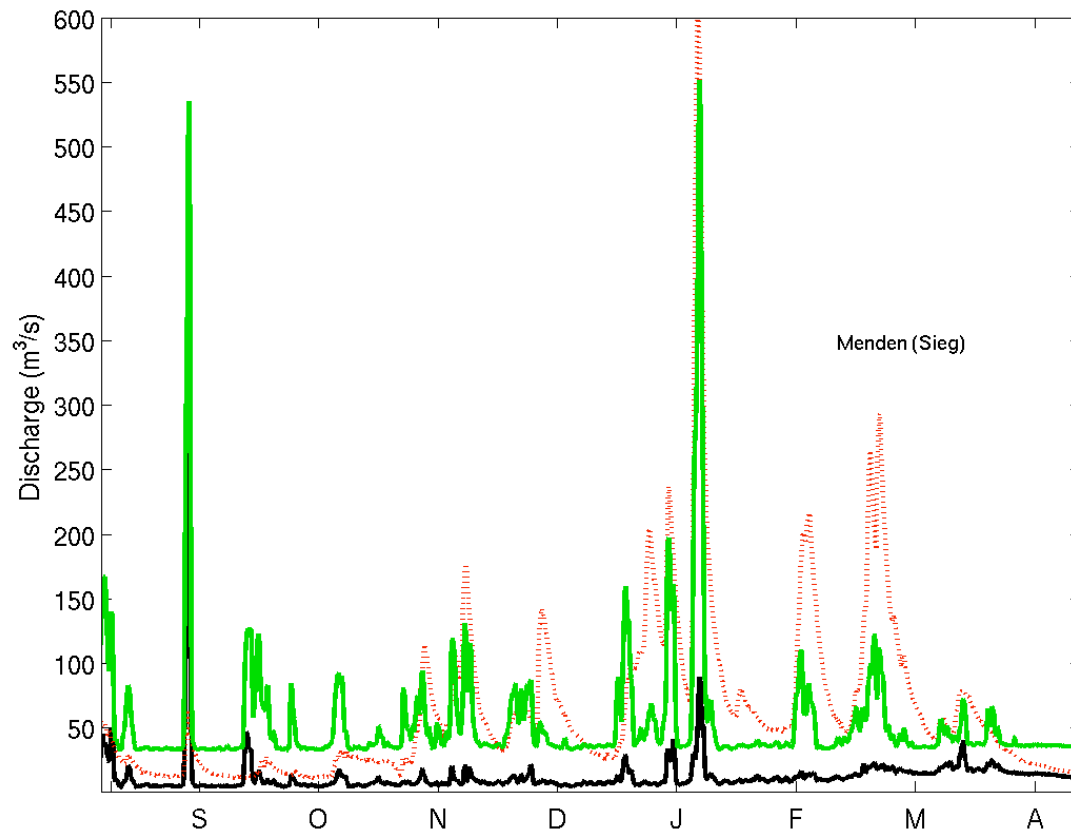
All combination effects which contain the significant effects influences discharge simulation

Conclusion

- Changes in vertical soil water transport parameterization show small improvements of the modelled discharge
- A radar based rainfall product is able to simulate discharge
- The operational version tends to drying out during longer simulation times
- A variable groundwater table improves the runoff calculation of TERRA-ML
- 2-level factorial design offers valuable clues to the sensitivity of infiltration rate parameterization and ground water table parameterization



Ground water table parameterization



2006/2007

$$R_{Sb \max} = 1.46E-4$$

$$R_{Sb \max} = 4.46E-4$$

$$f = 3.26$$

$$f = 2.90$$

$$I_{K1} = 0.0020$$

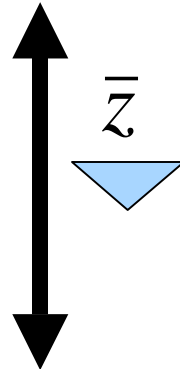
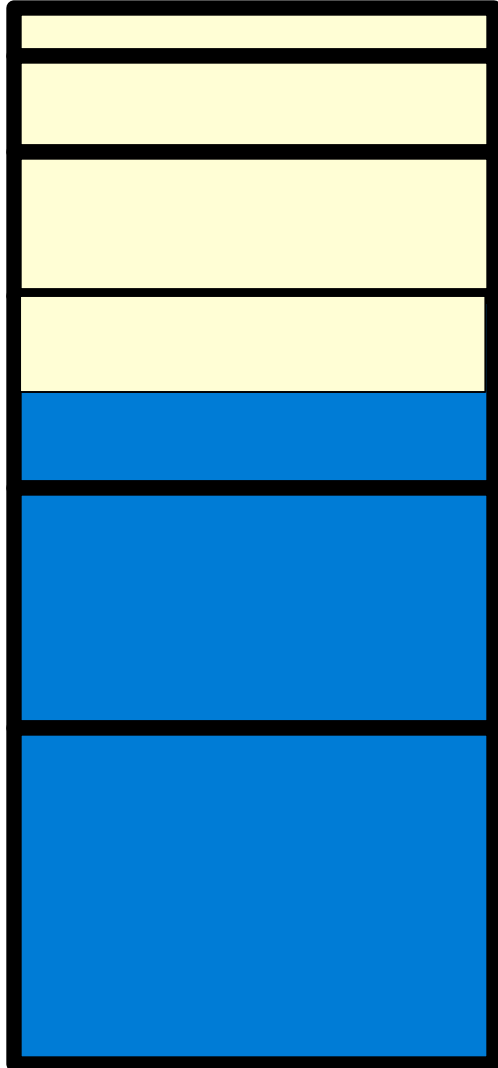
$$I_{K1} = 0.0004$$

$$I_{K2} = 0.0003 - 0.0035$$

$$I_{K2} = 20\%$$

Ground water table parameterization

$$i = 1 \dots n$$



subsurface runoff of the several layers changed as follows:

$$R_{b,j} = \left(\frac{K_{s,j}(zb_j - \bar{z})}{K_{s,j}(zb_j - \bar{z}) + \sum_{i=j+1}^n K_{s,i}\Delta z_i} \right) R_{Sb} \text{ , ground water table in layer } i = j$$

$$R_{b,i} = \left(\frac{K_{s,i}\Delta z_i}{K_{s,j}(zb_j - \bar{z}) + \sum_{i=j+1}^n K_{s,i}\Delta z_i} \right) R_{Sb} \text{ , ground water table over layer } i$$