H41F-0959. Conditioning of a mesoscale hydrologic model with proxy soil moisture fields

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1. Abstract

Multiscale monitoring and data assimilation techniques are fundamental to improve the predictability of mesoscale distributed hydrologic models.

In-situ measurements along with remote sensed information can be used to condition the parametrization of distributed model aiming at reducing prediction uncertainty of both energy and mass balances. One of the key state variables responsible for the feedback mechanisms in the land-surface-atmosphere system is soil moisture. This variable, on the contrary to other water fluxes, has a long memory and depends greatly on local conditions.

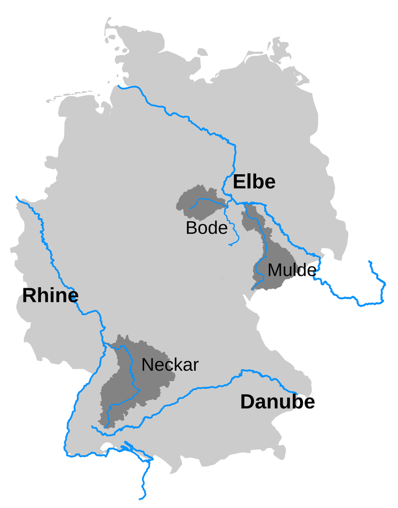
The spatial distribution of soil moisture is therefore crucial to determine the spatial patterns of both surface runoff and actual evaporation. There are a number of proxies that can be used to describe the evolution of this state variable. They can be obtained at different resolutions, for example, the land surface temperature (LST) of the MODIS (NASA) sensor (1 x 1) km or the surface soil moisture (SSM) data based on ERS and METOP scatterometers (12.5 x 12.5) km.

2. Research Questions

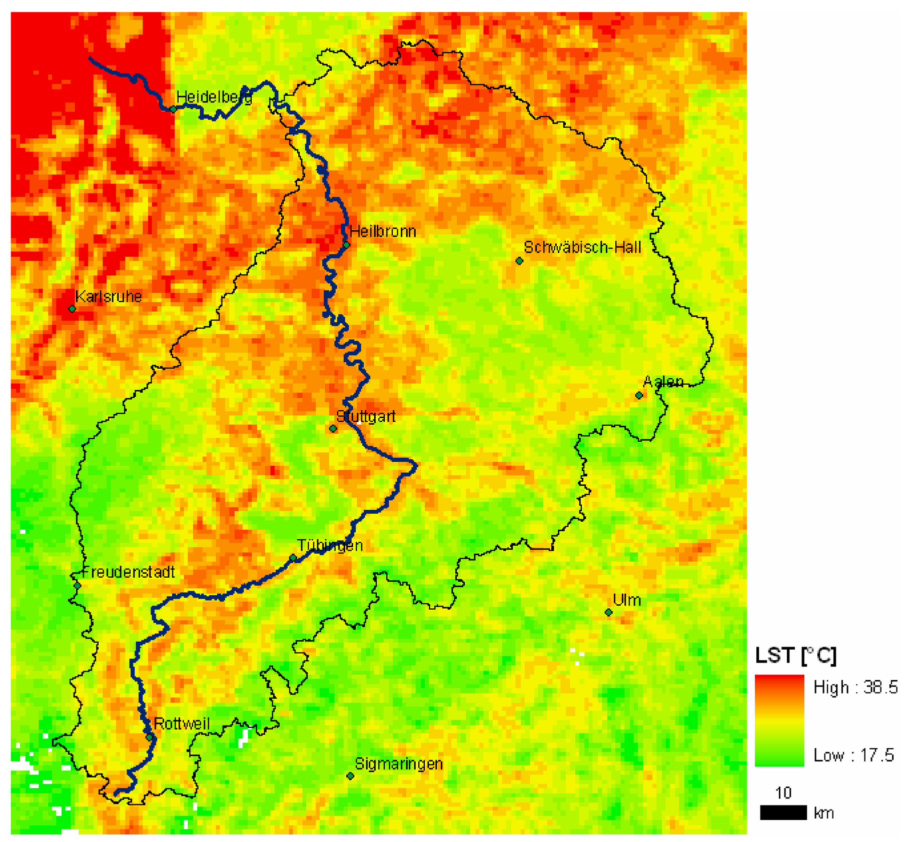
1. Can remotely sensed products be assimilated in a mesoscale hydrologic model as proxies for the soil water content?
2. How can these products be assimilated to improve model performance?

3. Study Areas

- **Neckar**: 12 700 km^2
- **Bode**: 3 300 km^2
- **Mulde**: 2 700 km^2



Location of the basins within Germany

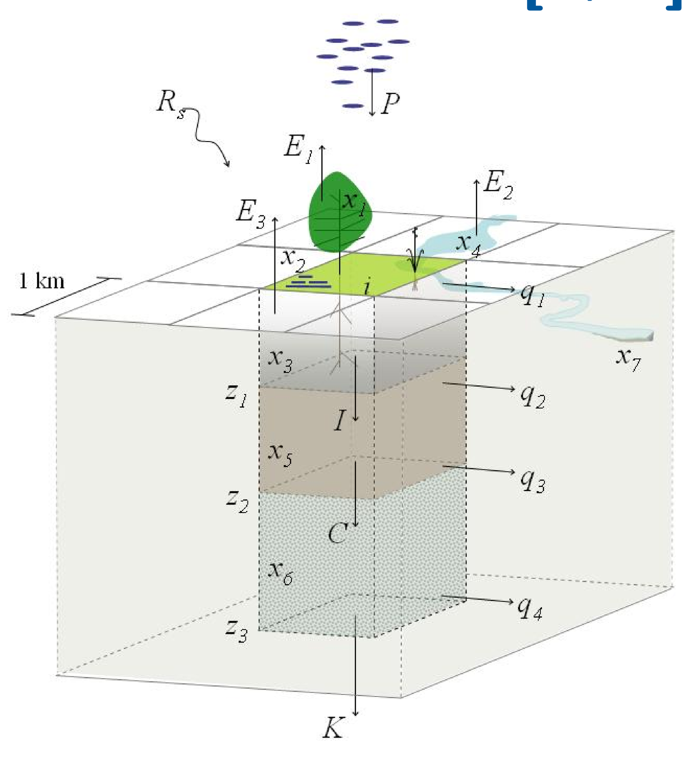


Daily land surface temperature in Neckar basin 2005-08-31 14:00 MODIS[1]

Variables of interest

- **Porosity** [-] $=\Theta_s$, of the top soil layer, d = 20 mm.
- **Maximum water storage** [mm] $= d\,\Theta_s$, in d = 20 mm soil depth.
- **Water content** [mm] $= d\,\Theta = x_3$, in 20 mm soil depth
- **Land surface temperature** $[^\circ C] = T_s$

4. mHM Model [2, 3]



State variable at cell i, time t

State equations: cell i, time t:

$$\dot{\mathbf{x}}_i(t) = \mathbf{f}(\mathbf{x}_i, \mathbf{u}_i, \boldsymbol{\beta}_i) + \boldsymbol{\eta}_i(t) \quad \forall i \in \Omega$$

Output: runoff:

$$\mathbf{q}_l(t) = \mathbf{g}(\mathbf{x}, \mathbf{u}, \boldsymbol{\beta}) + \boldsymbol{\epsilon}_l(t)$$

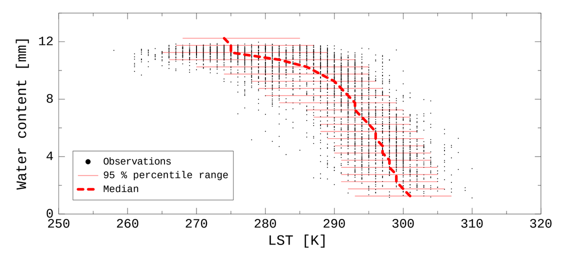
Multiscale parametrization[3]:

$$\beta_{ki}(t) = \mathrm{O}_k \Big\langle \boldsymbol{u}_j(t), \boldsymbol{\gamma} \quad \forall j \in i \Big\rangle_i$$

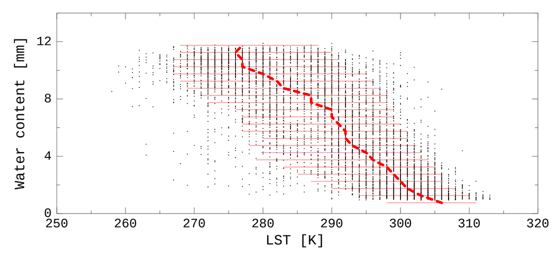
Model efficiency[3]:

NSE [0.7-0.9], RMSE [0.45-0.95] mm/d

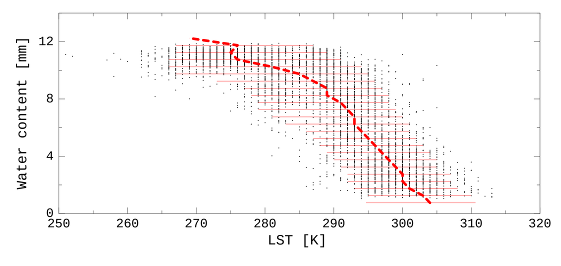
5. Variability of Modelled Soil Water Content vs. LST



Forested areas (e.g. coniferous, deciduous)

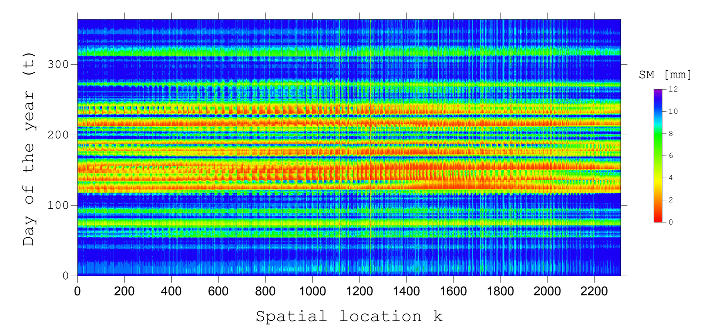


Impervious cover (e.g. settlements, roads)

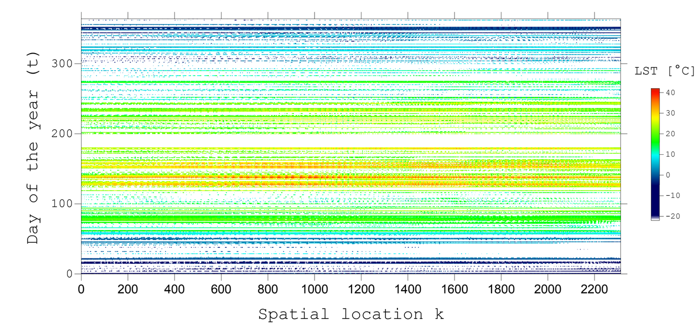


Permeable cover (e.g. cropland, grassland)

Let $\mathbf{D} = \{(i,j) \quad 1 \le i,j \le n\}$ denote a $n \times n$ integer lattice (domain). For simplicity, let k denote an identifier of the coordinates (i,j). Let $\mathbf{Z}^t = \{z_{i,j}\},\ (i,j) \in \mathbf{D}$ denote a variable of interest (e.g. T_s, $d\,\Theta$) at time t. Space-time plots of these variables can be seen below



Spatio-temporal variability of modeled soil water content during year 2001



Spatio-temporal variability of LST during year 2001

On these fields, **local relationship operators** of a variable $\mathbf{Z}$ may be of practical interest.

Example:

Let $\eta(\mathbf{Z})$ denote the **degree of dominance** of the cell k at time t with respect to its immediate eight neighbors (i.e. $c = 2$) $\mathcal{N}(c)$, thus,

$$\eta_k = \eta_{i,j} = \Big| \big\{ z_{i,i} - z_{k,l} < 0,\ (i,j) \in \mathcal{N}_{i,j} \big\} \Big|$$

where

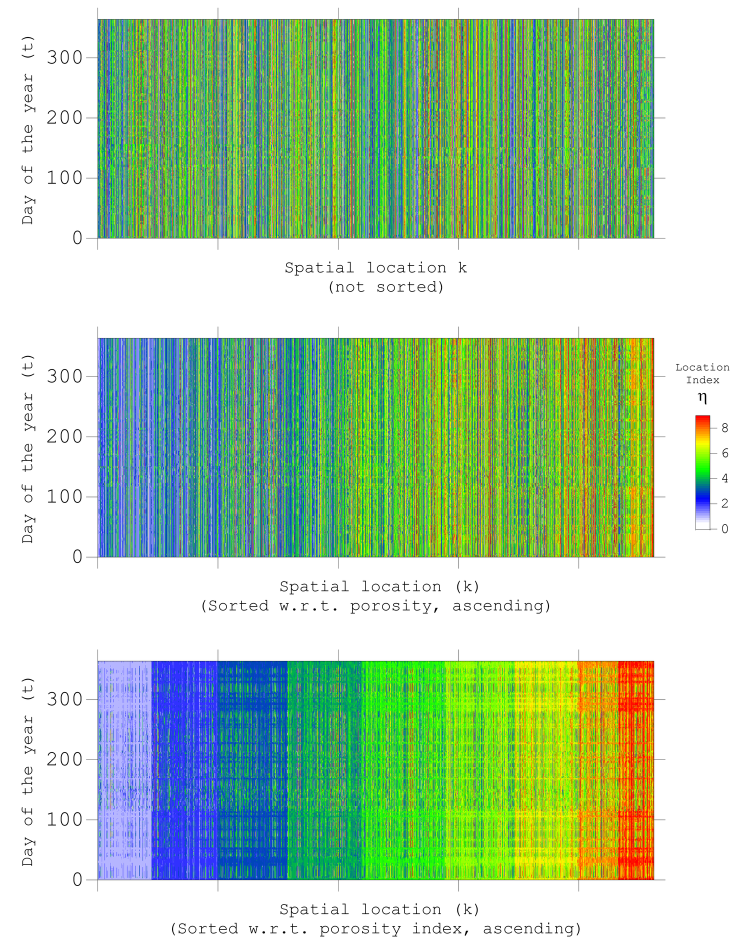
$$\mathcal{N}_{i,j} = \big\{ (k,l) \in \mathbf{D} \quad 0 < (k-i)^2 + (l-j)^2 \le c \big\}$$

c denotes the neighborhood configuration, and $|\bullet|$ is the cardinality of the set. If $c = 2$, then the index η_k can vary between $\eta_k \in \{1, \ldots, 8\}$.

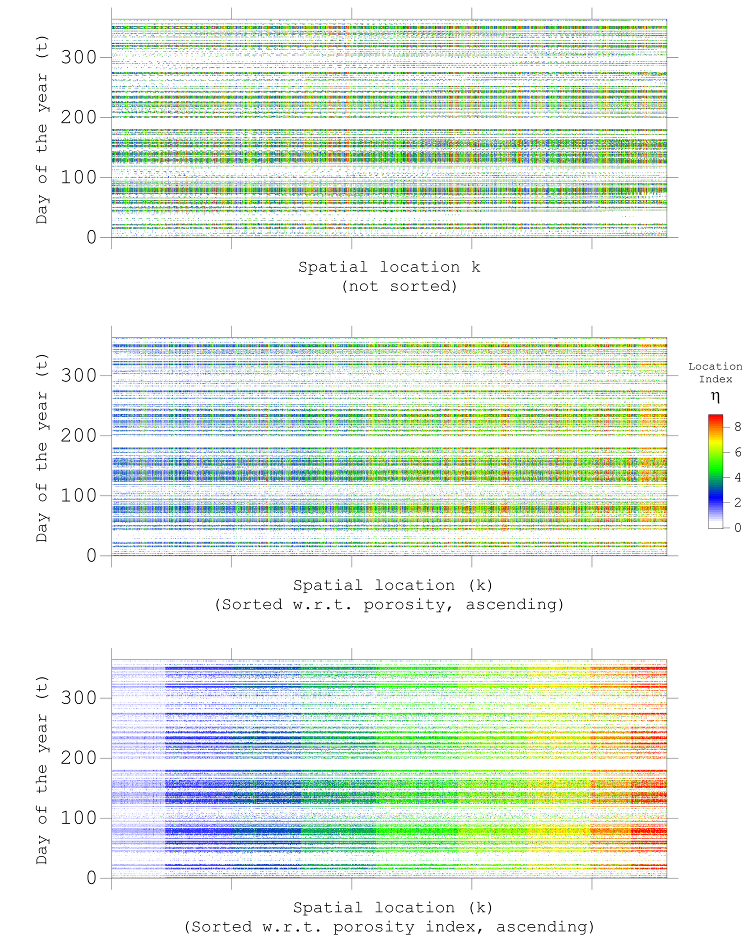
6. Searching for Patterns in $\eta(\mathbf{Z})$

Is there a mapping $\mathcal{M}$ such that the ordering of

$$\mathcal{M}\big(\eta(d\,\Theta)\big) \sim \mathcal{M}\big(\eta(T_s)\big)?$$



Space-time plot for $\eta(\mathbf{Z})$, with $\mathbf{Z} = d\,\theta =$ modeled soil water content for permeable cover during 2001



Space-time plot for $\eta(\mathbf{Z})$, with $\mathbf{Z} = \frac{d\,\theta_s}{T_s} =$ inverse of LST (normalized with θ_s) for permeable cover during 2001

7. Conclusions

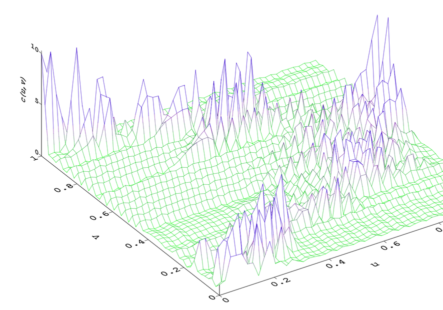
Useful estimators were found in this study:

Ordering relationship for the degree of dominance

$$\mathcal{M}\big(\eta(d\,\Theta)\big) \approx \mathcal{M}\Big(\eta\big(\frac{d\,\Theta_s}{T_s}\big)\Big)$$

with $\mathcal{M}$ being the permutation according to ascending $\eta(\Theta_s)$.

Stochastic dependence $c(u,v)$: probability density function between marginals $u = F(T_s)$ and $v = F(\Theta)$.



Copula between simulated Θ and T_s for permeable cover during 2001

References

[1] NASA, http://modis-land.gsfc.nasa.gov/.

[2] L. Samaniego, A. Bárdossy, and R. Kumar, "Streamflow prediction in ungauged catchments using copula-based dissimilarity measures," *Water Resour. Res.*, 2009, in press.

[3] L. Samaniego, R. Kumar, and S. Attinger, "Multiscale parameter regionalization of a grid-based hydrologic model at the mesoscale," *Water Resources Research*, 2009, in Press.

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