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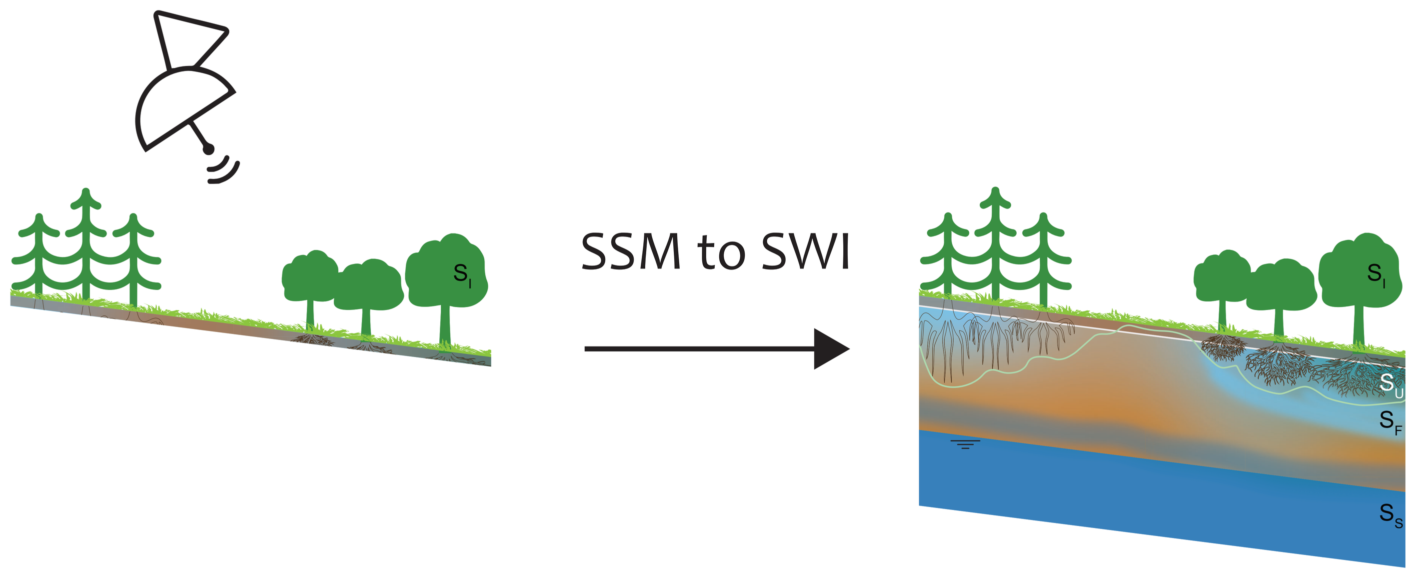
Catchment-scale connection between vegetation accessible storage and satellite-derived Soil Water Index

Introduction

Satellite surface soil moisture estimates are limited to the upper-most few centimeters of the soil. However, for hydrological applications, we are interested in the water stored in the root-zone of vegetation, as it controls the partitioning of precipitation to drainage and evaporation.



The Soil Water Index (SWI) approximates root-zone soil moisture from surface soil moisture (SSM), through:

$$SWI(t_n) = SWI(t_{n-1}) + K_n \cdot (SSM(t_n) - SWI(t_{n-1}))$$
$$K_n = \frac{K_{n-1}}{K_{n-1} + e^{-\frac{(t_n - t_{n-1})}{T}}}$$

Wagner et al. 1999
Albergel et al. 2008

However, how to meaningfully estimate the value of the characteristic time length *T* parameter of the Soil Water Index to infer root-zone soil moisture from near-surface soil moisture?

Optimal T values are linked to the **phase lag** between **seasonal signals** of **water supply** (precipitation) and **water demand** (evaporation) and therefore to **catchment-scale vegetation accessible water storage capacities.**

Identify T_{opt}

- Calibrate model (Fig. 1) on observed runoff to estimate root-zone soil moisture in Meuse catchments (Fig. 2)
- Transform surface soil moisture (SSM) to Soil Water Index (SWI) for different values of T (Fig. 3)
- Identify T_{opt} for each catchment from highest Spearman correlation (Fig. 4)

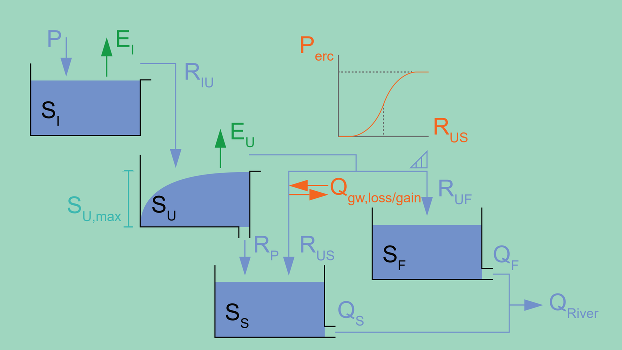


Fig. 1: Lumped process-based hydrological model

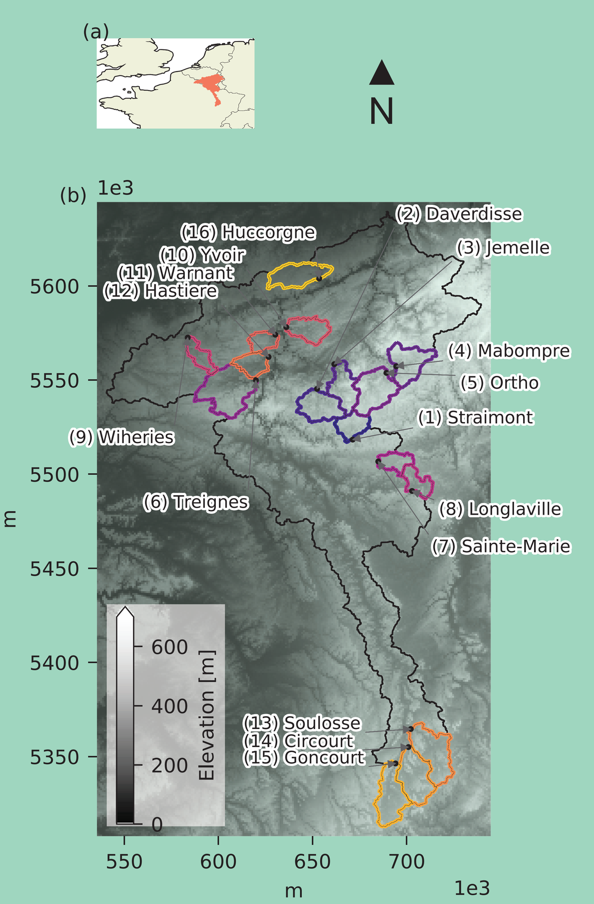


Fig. 2: Study catchments in the Meuse River Basin (Northern Europe)

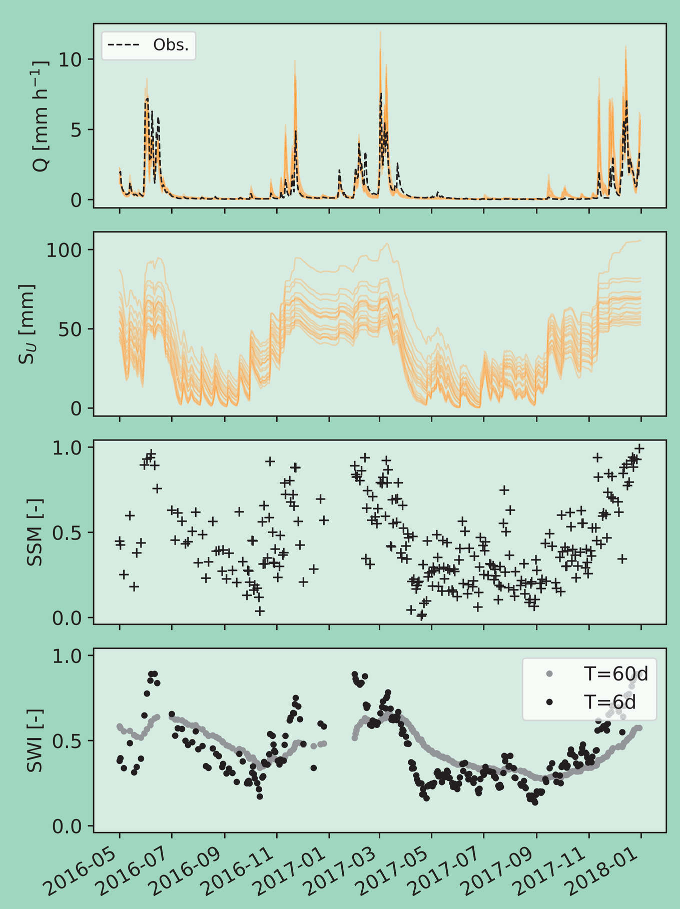


Fig. 3: Modeled and observed runoff, modeled root-zone soil moisture, SSM1km surface soil moisture and Soil Water Index for the Meuse at Goncourt

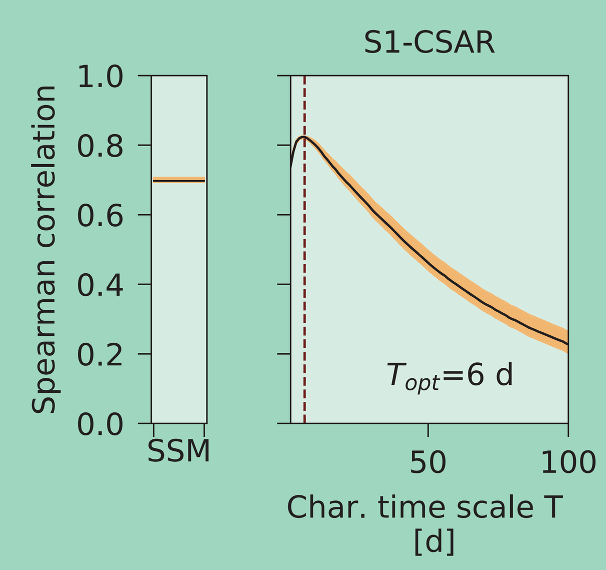


Fig. 4: Spearman rank correlation between time series of modeled root-zone soil moisture (Su) and SWI for values of *T*

Understand T_{opt}

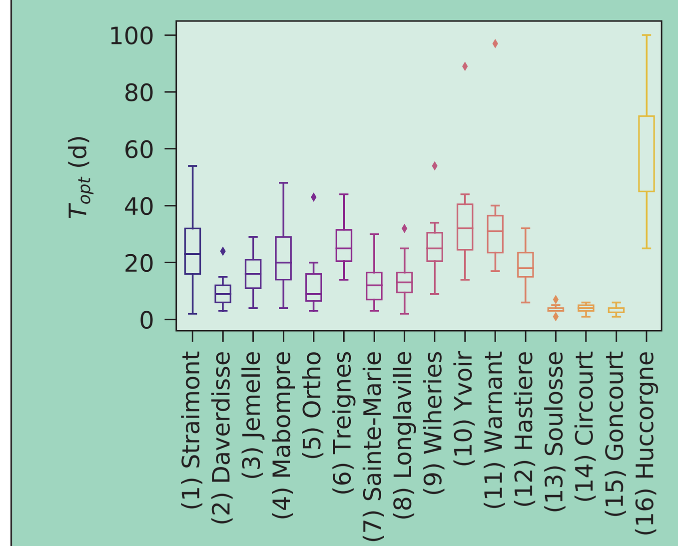


Fig. 5: T_{opt} range across all satellite SSM products for the study catchments

- Median optimal T_{opt} value in the Meuse of 17 days, however, significant differences between catchments (1-98 days), Fig. 5
- T_{opt} shows a strong relation with root-zone storage capacities and other physical catchment characteristics (Fig. 6)

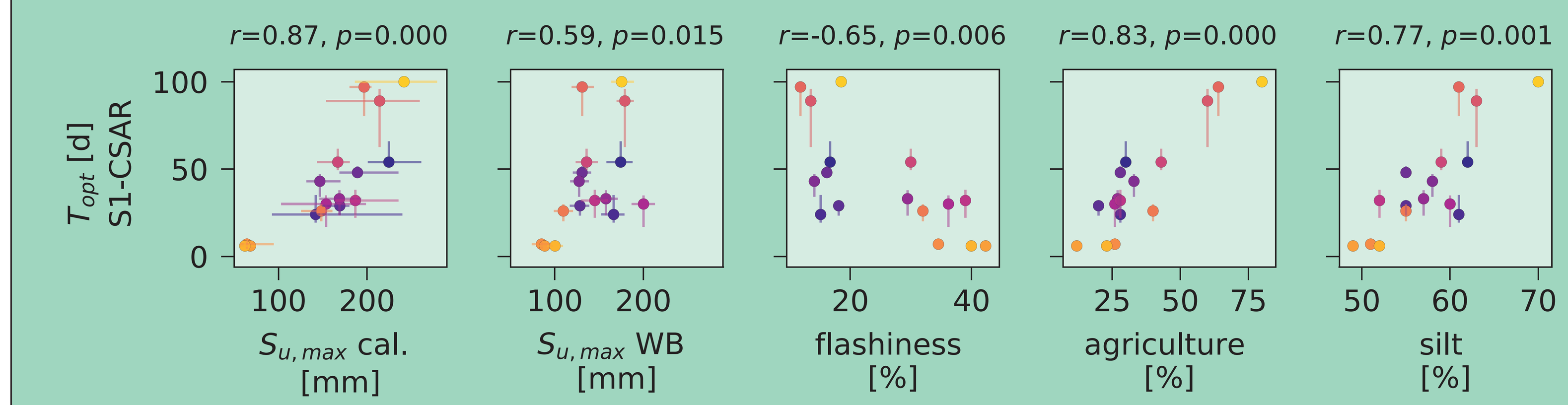


Fig. 6: T_{opt} as a function of calibrated (cal.) and water-balance (WB) derived root-zone water storage capacities ($S_{u,max}$), flashiness index, percentage agriculture and silt for the study catchments

Conclusions

- Previously T_{opt} was linked to an undefined storage in the subsurface
- We now show a strong relation with root-zone storage capacity
- This is useful to generate estimates of root-zone soil moisture from satellite surface soil moisture, as they are a key control of the reponse of hydrological systems.

Bouaziz et al., 2020. WRR https://doi.org/10.1029/2019WR026365