Towards an operationally capable satellite-based 0-100 cm soil moisture dataset from C3S

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Global Gravity - based Groundwater Product
G3P

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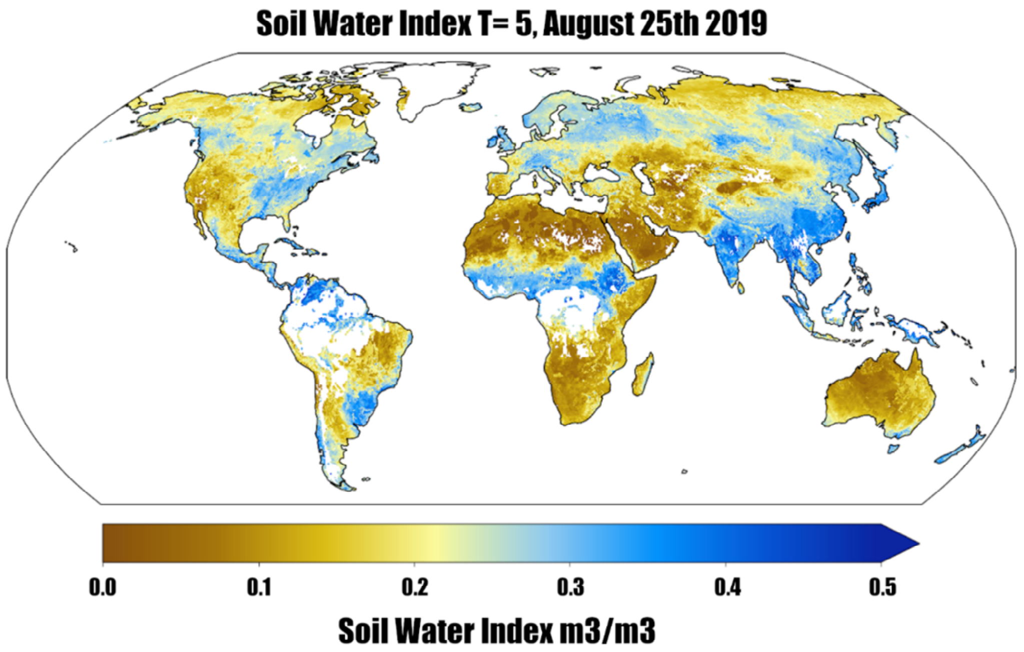
SWI calculation

SWI (Wagner et al. 1999, Albergel et al. 2008) is calculated from surface soil moisture (SSM) as a function of time needed for infiltration and can be used as a simple approximation of root-zone conditions.

$$SWI_T(t_n) = SWI_T(t_{n-1}) + gain_T(t_n)(SSM(t_n) - SWI_T(t_{n-1}))$$

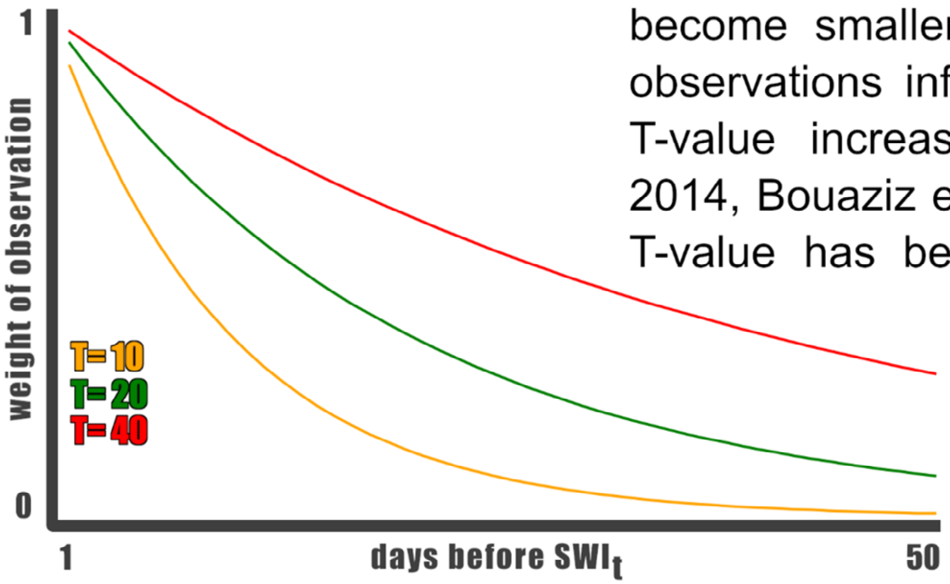
$$gain_T(t_n) = \frac{gain_T(t_{n-1})}{gain_T(t_{n-1}) + e^{-\frac{t_n - t_{n-1}}{T}}}$$



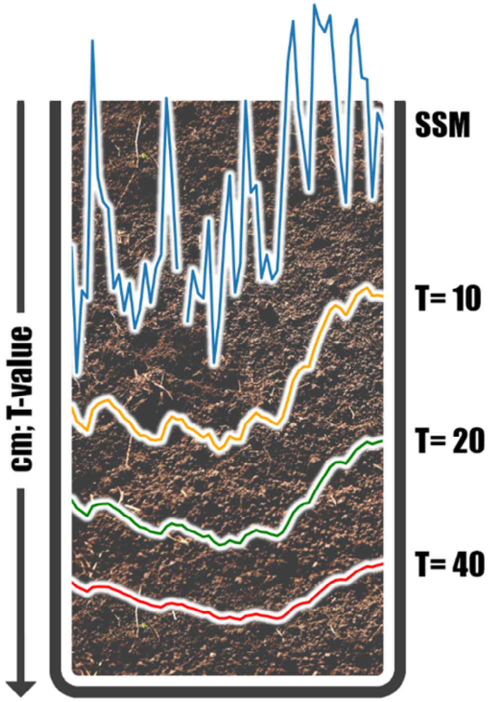
Where: t_n = obs. time of the current measurement, t_i = obs. time of the previous measurement, e = exponential function, T = t-value.

Calculation can be initialized at any time when SSM becomes available with the values: $SWI_T(t) = SSM(t)$, $gain_T(t) = 1$, $t_{n-1}=t$.

SWI characteristic T-value



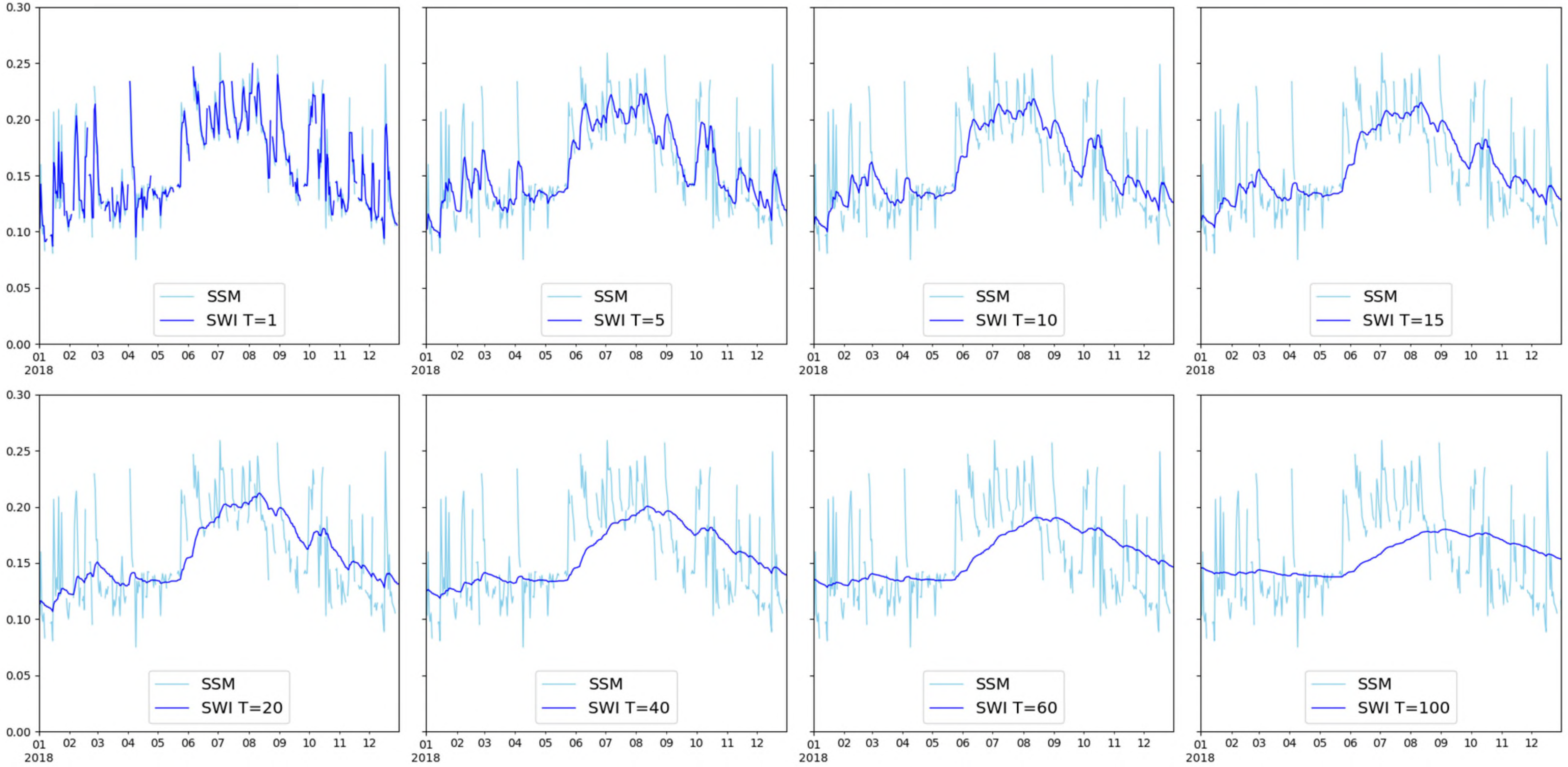
T-value determines how fast the weights become smaller and how strongly past SSM observations influence current SWI. Generally, T-value increases with depth (Paulik et al. 2014, Bouaziz et al. 2020) although the optimal T-value has been demonstrated to vary with factors such as soil characteristics (Wang et al. 2017) and climate (Albergel et al. 2008).



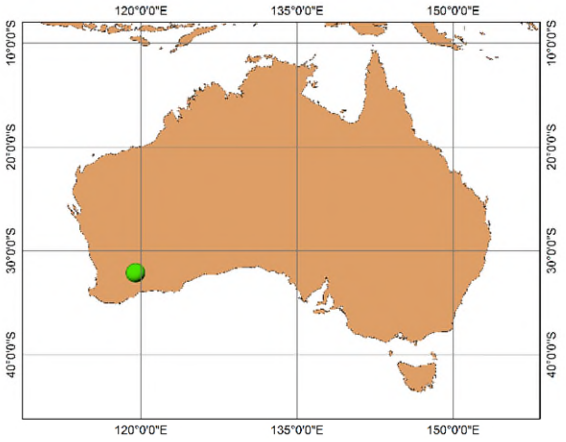
i.e. if t-value is 5 and a SSM measurement was taken 10 days before t_n then this observation would receive the weight $e(10/5)=0.135$. T value of 20 in the same case would increase the weight to $e(10/20)=0.607$.

Data coverage

The higher the T-value, the more weight it gives to older observations. Therefore, high T-values representative of deeper soil-layers are much less affected to short-lived precipitation events.

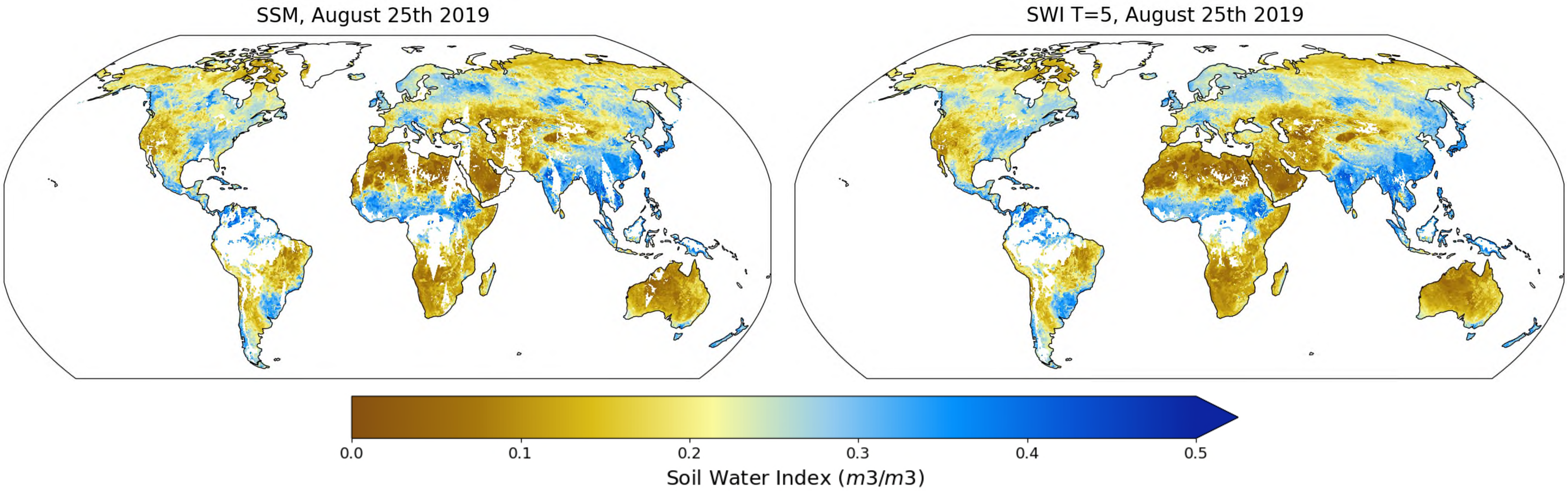


2018 time series comparison with SSM for a point in SW Australia (119.625, -32.125)



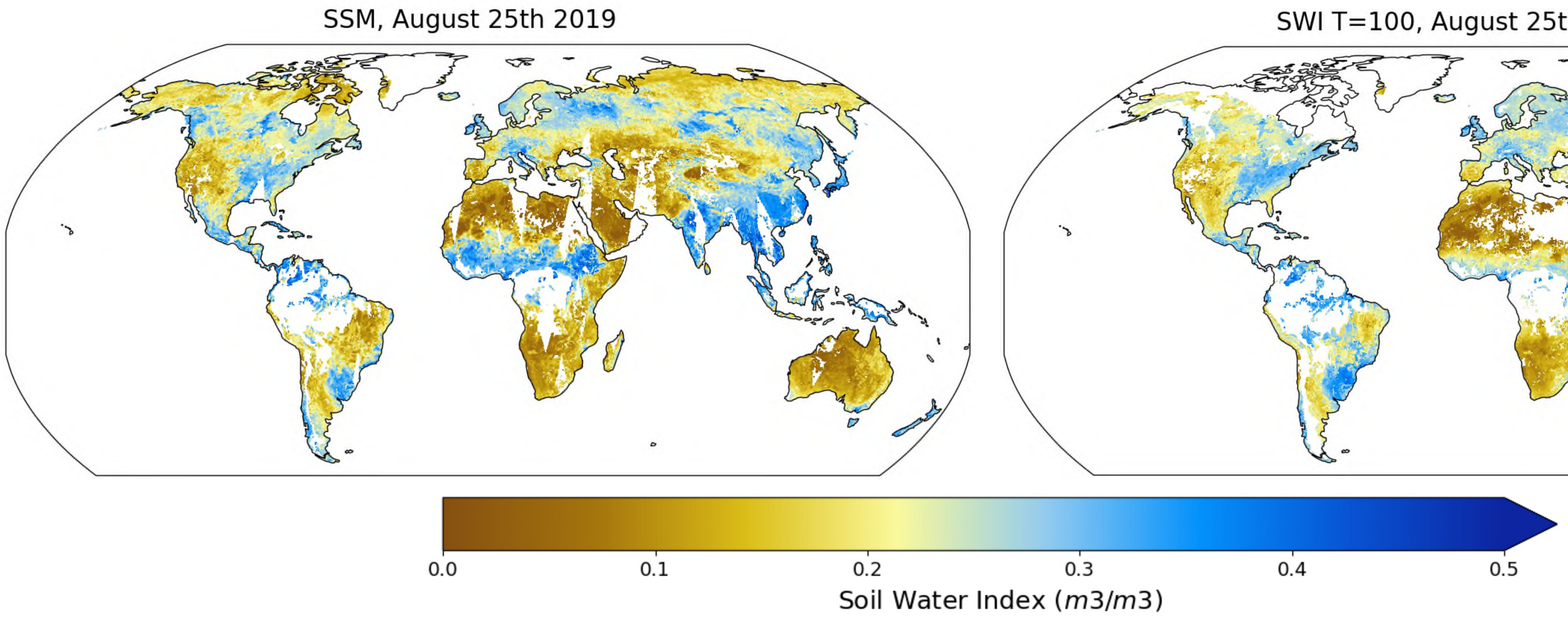
Data coverage

As SWI weighs and utilizes past observations, where SSM data is unavailable SWI can still be calculated given that enough data density has been achieved. Therefore, SWI can achieve a greater spatial coverage than the input SSM dataset, especially for lower T-values which represent the topmost layers of the soil and have relatively low quality flag thresholds.



Data coverage

As high T-values assign more weight to older observations and represent deeper soil layers, they require higher data density. This greatly affects their spatial coverage especially in the northern latitudes where SSM data retrievals are periodically problematic due to snow and frozen ground and each spring Q-flag values need to be built up anew.



G3P

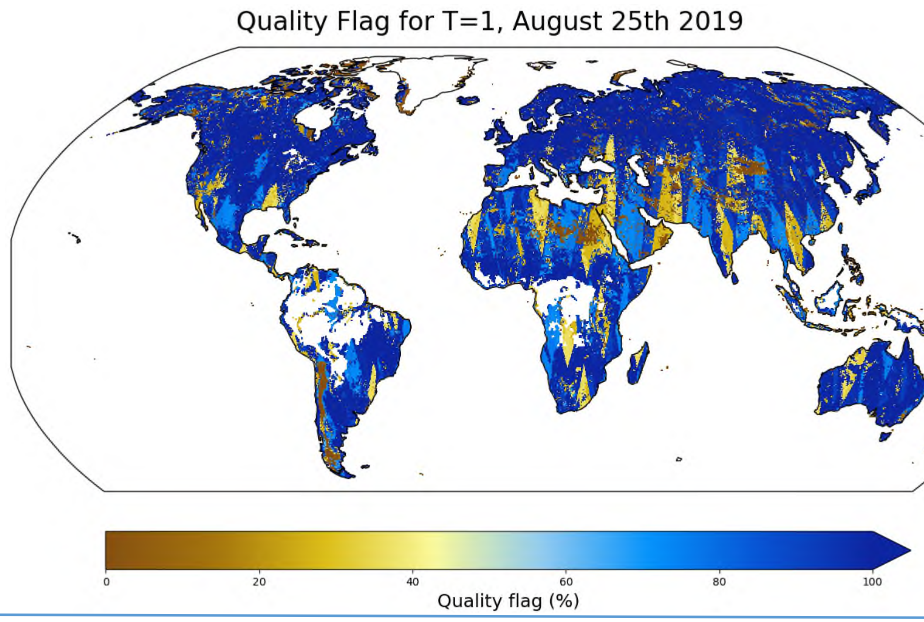
Horizon2020

Quality flags (Q-flags)

Q-flags indicate the density of data used to calculate SWI and are based on empirical experiments by Bauer-Marschallinger and Paulik (2019). Q-flags are calculated recursively as follows:

$$qflag_T(t_i) = \begin{cases} 1 + qflag(t_{n-1}) \cdot e^{-\frac{t_n - t_{n-1}}{T}}, & if\ SSM\ at\ t_i\ is\ available(t_i = t_n) \\ qflag(t_{n-1}) \cdot e^{-\frac{t_i - t_n}{T}}, & if\ SSM\ at\ t_i\ is\ unavailable \end{cases}$$

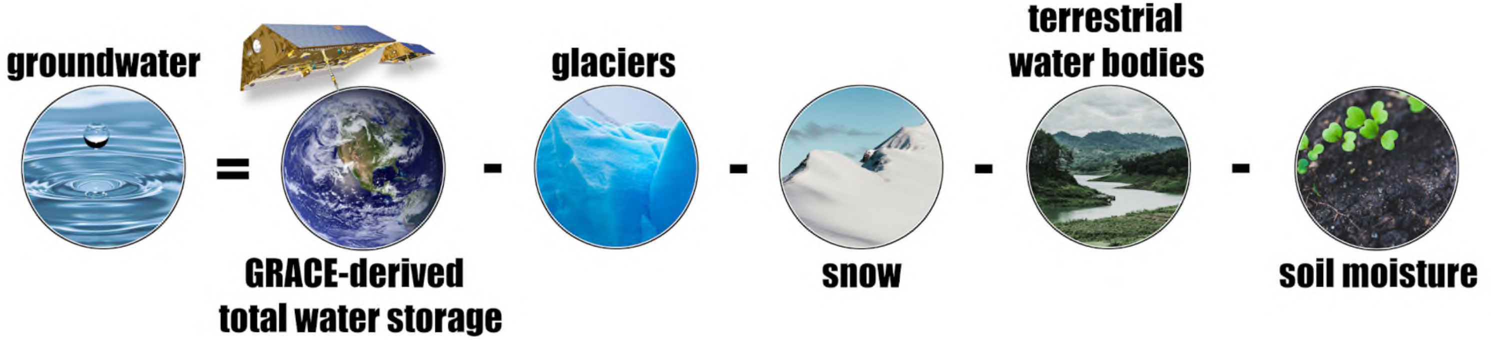
Data are masked when the flag values fall below their respective thresholds, individually calculated for each T-value from *T*-value 1: 35% to *T*-value 100: 70%.

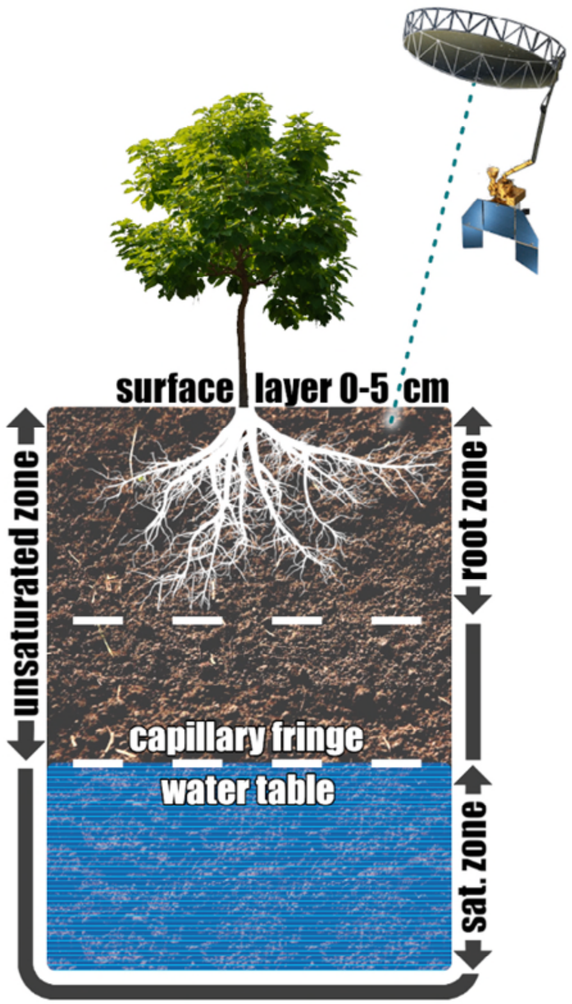


G3P concept

Global **G**ravity-based **G**roundwater **P**roduct (G3P) basic idea:

- Resolve for groundwater storage changes by substracting individual water storage compartments from total water storage variations derived from GRACE/FO gravity data.
- G3P also aims to provide an operational global root-zone soil moisture product derived from Copernicus Climate Change Service (C3S) Soil Moisture data available in near-real time using SWI.

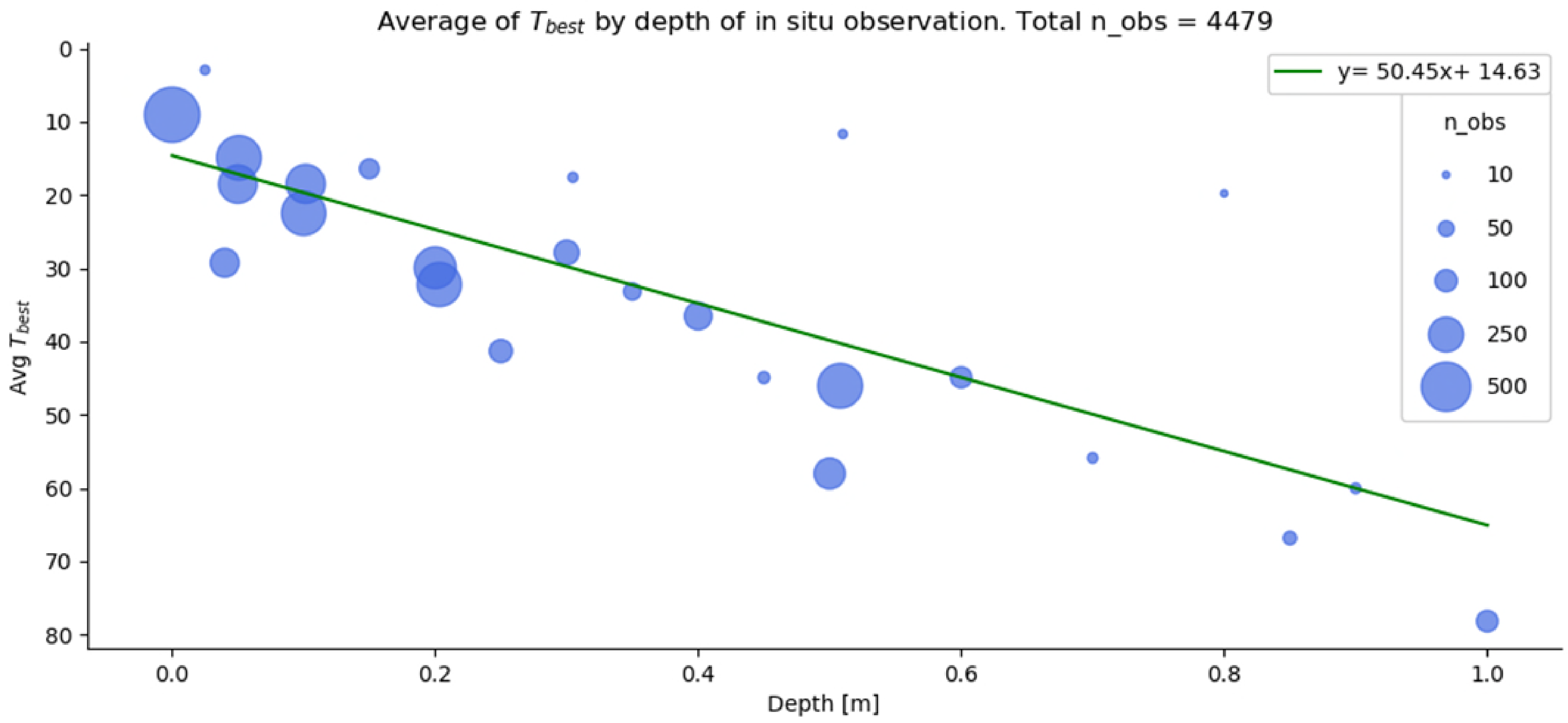




From SWI to RZSM

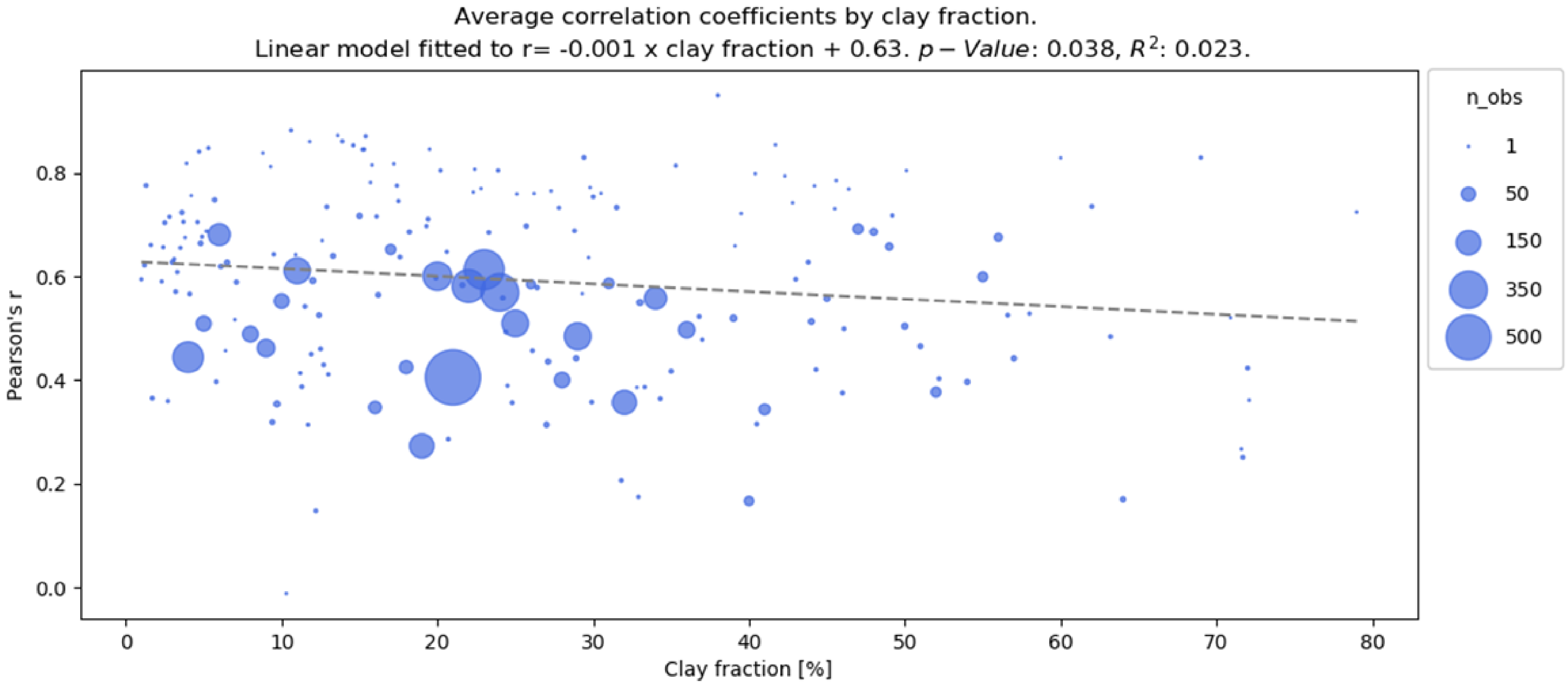
- Here a linear regression modelling the relationship between T-value and soil depth is fitted to a total of 4479 in situ time series across 45 unique sensor depths, located at 1276 ISMN stations.

- Subsequently, the average highest correlating T-value (Avg T_{best}) per depth is selected to represent root-zone soil moisture (RZSM) conditions at 10 cm intervals to a maximum depth of 100 cm.



T-value calibration

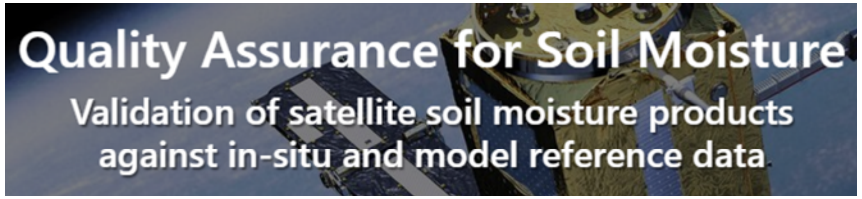
The influence of soil and climate characteristics on the relationship between T-value and soil depth was previously examined by others (Albergel et al. 2008, De Lange et al. 2008, Paulik et al. 2014) and produced varying and sometimes contrary results. Here the influence of soil and climatic parameters on the T_{best} will also be examined, together with additional parameters such as vegetation density and landcover.



Soil Water Index is calculated from C3S Soil Moisture v201912 COMBINED. Visit https://cds.climate.copernicus.eu/portfolio/dataset/satellite-soil-moisture for more information and to access the data.

SWI dataset was validated against in-situ data from the International Soil Moisture Network https://ismn.earth

Validation procedure was completed with QA4SM, an online soil moisture data validation framework available at https://qa4sm.eu



References:

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