Towards long-term satellite root-zone soil moisture: 40-year Soil Water Index dataset from ESA CCI COMBINED Soil Moisture product

Adam Pasik[1], Bernhard Bauer-Marschallinger [1], Wolfgang Preimesberger [1], Tracy Scanlon [1], Wouter Dorigo [1], Sebastian Hahn [1]

[1]Technological University of Vienna, Geodesy and Geoinformation, Vienna, Austria

Contact: adam.pasik@geo.tuwien.ac.at

Global Gravity - based Groundwater Product

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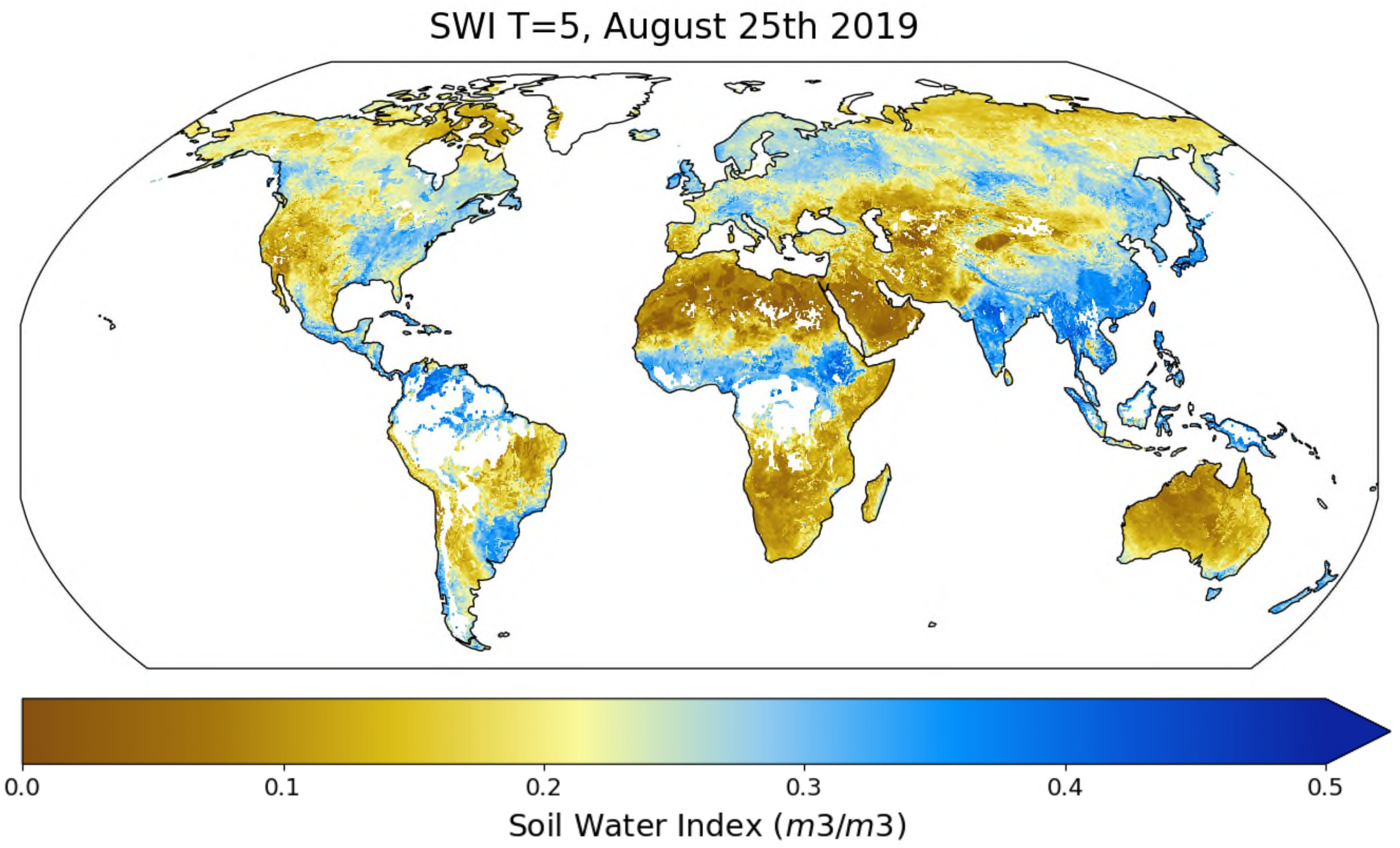
Soil Water Index

- Soil water index (SWI) 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.
- Here SWI is calculated for eight T-values (1, 5, 10, 15, 20, 40, 60, 100), where T-value is a temporal length ruling the infiltration; depending on the soil characteristics it translates into different soil depths.



SWI calculation

SWI is calculated from SSM using a recursive formulation proposed by Albergel et al. (2008) which allows production of an operational product in near real-time:

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

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

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.

T-value determines how fast the weights become smaller and how strongly SSM obs. taken in the past influence current SWI.

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.

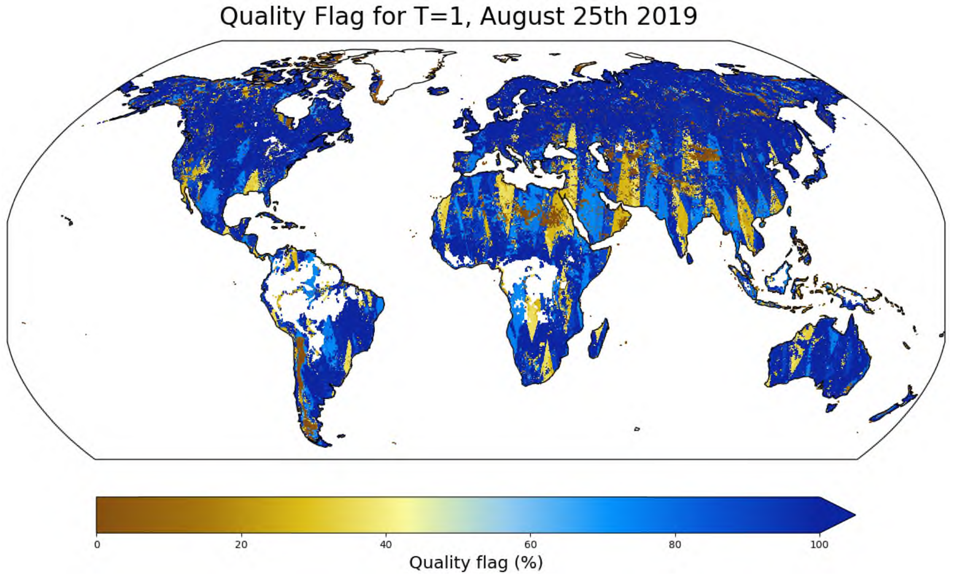
Quality flags (Q-flags)

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:

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

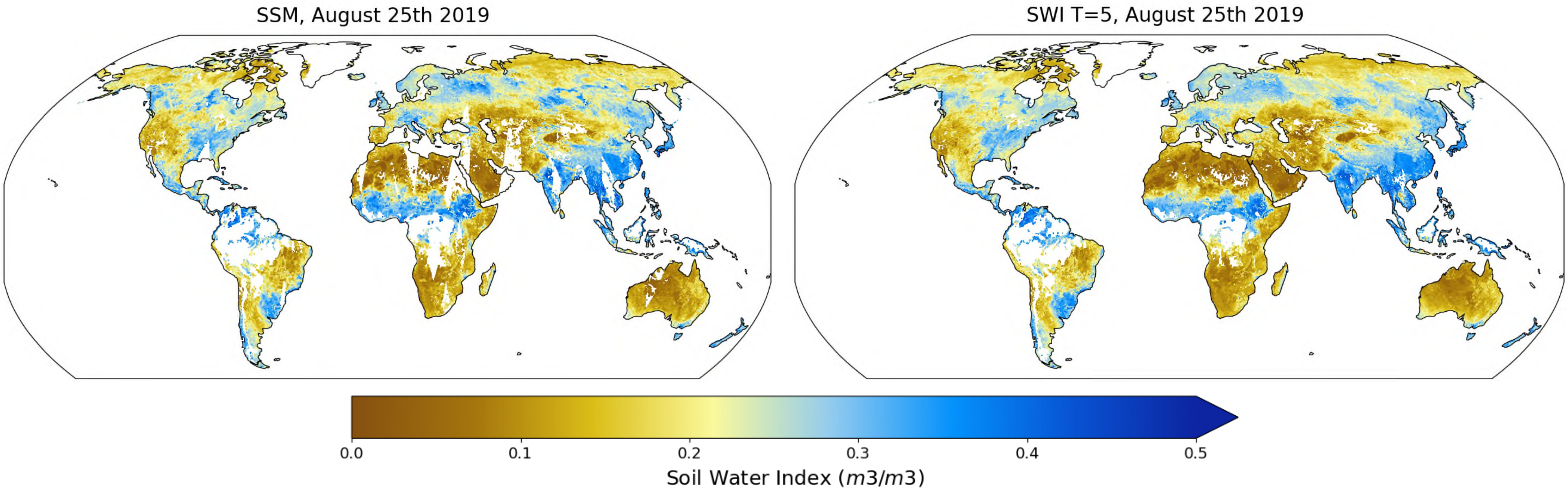
Data are masked when the flag values fall below their respective thresholds:

T-value 1:	35%,	*T*-value 20:	55%,
T-value 5:	45%,	*T*-value 40:	60%,
T-value 10:	50%,	*T*-value 60:	65%,
T-value 15:	53%,	*T*-value 100:	70%.



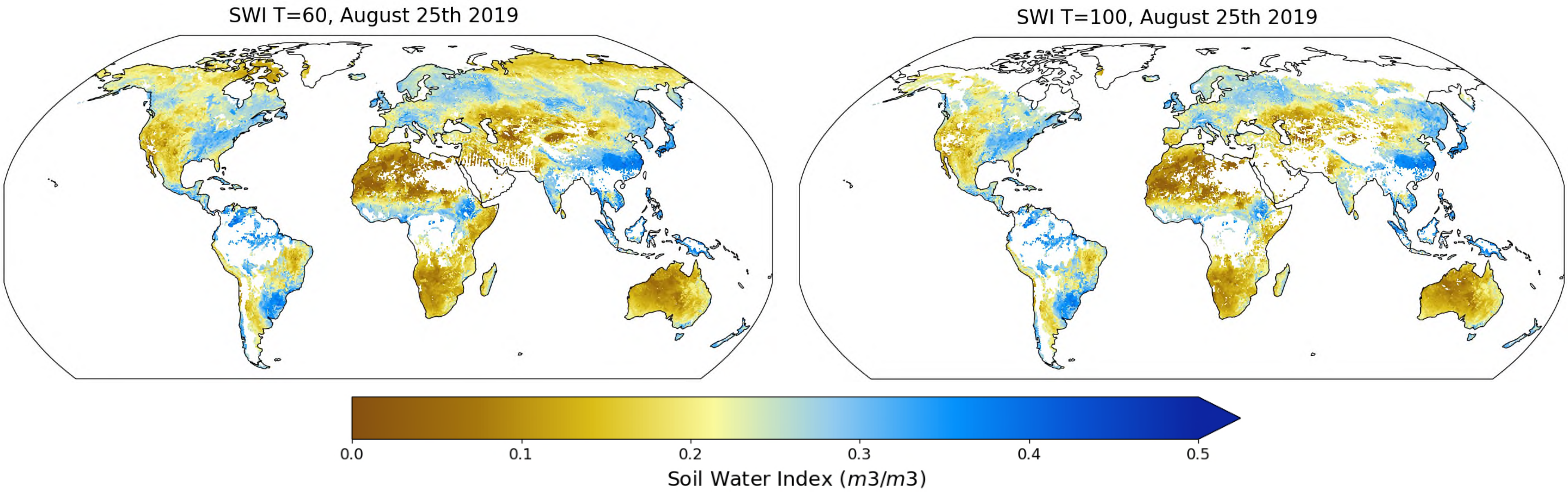
Data coverage

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.



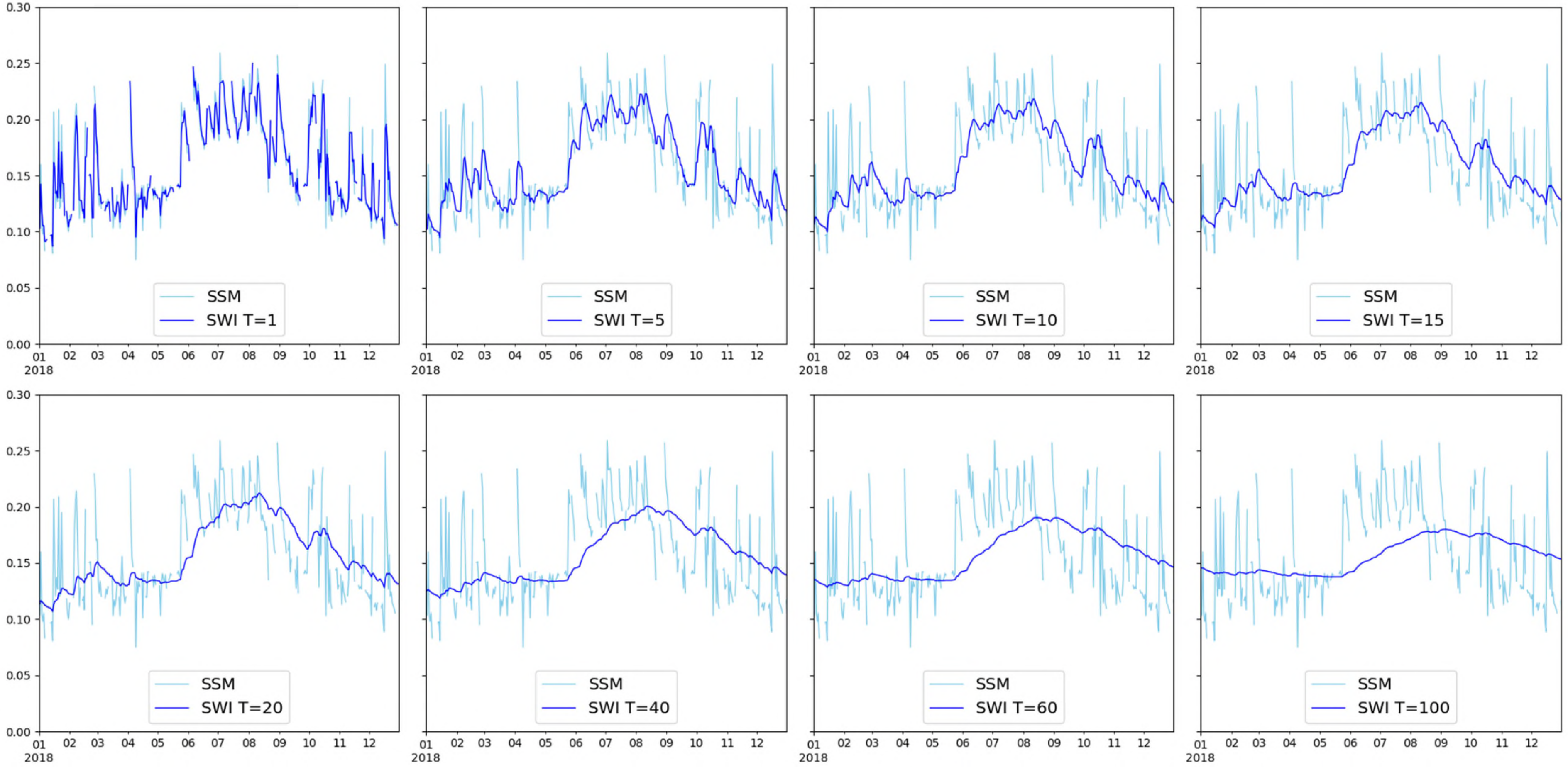
Data coverage

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.

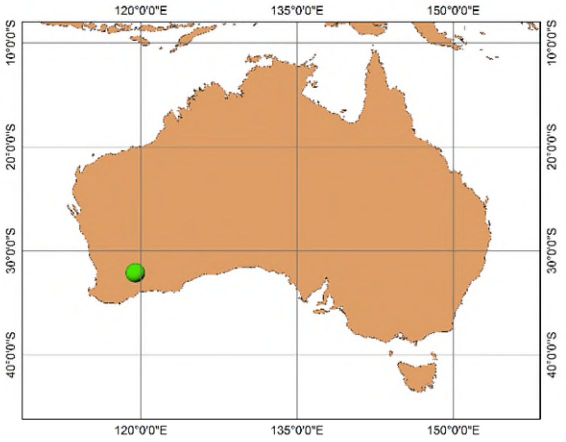


Data coverage

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.

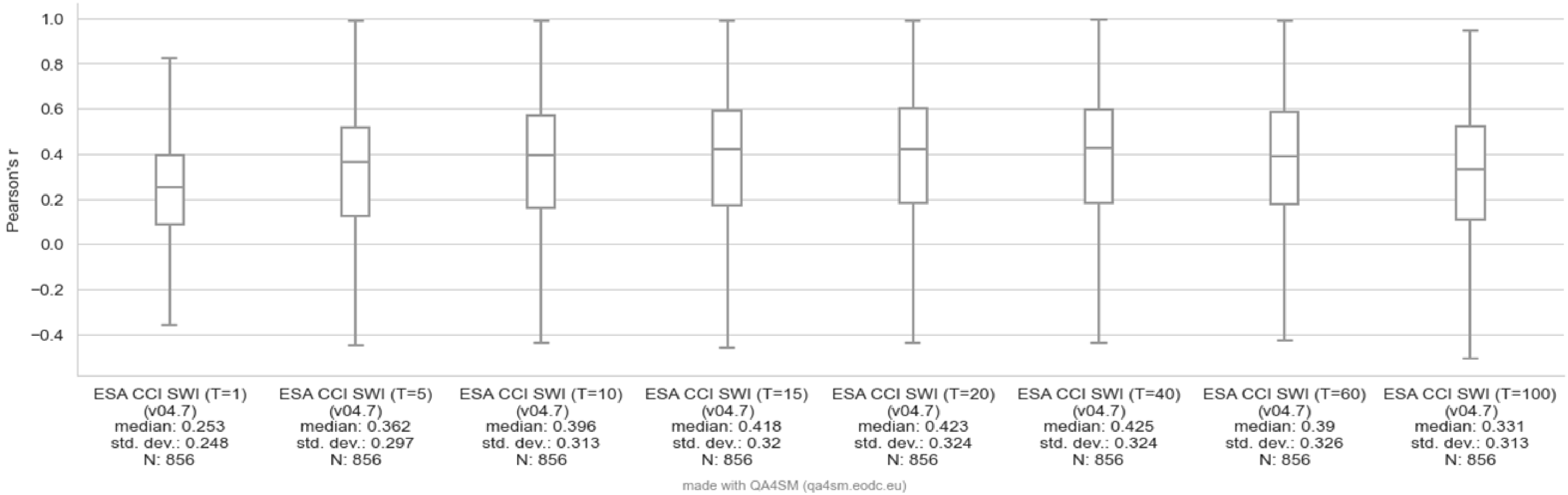


2018 time series comparison with SSM for a point in SW Australia (119.625, -32.125)



Validation against ISMN

Correlation (Pearson's r) for a selection of SWI T-values and in-situ data reference data (ISMN_V20191211) for soil depth 40-50cm



Global validation against in-situ data from the International Soil Moisture Network (ISMN) shows that generally the best-fitting T-value increases with the soil depth.

Differences in correlation coefficient between T-values are sometimes very small, especially in the topmost layers of the soil (i.e. 0-20 cm). Our results are consistent with the results presented in Paulik et al. (2014).

Validation

Reproduced from Paulik et al. (2014).

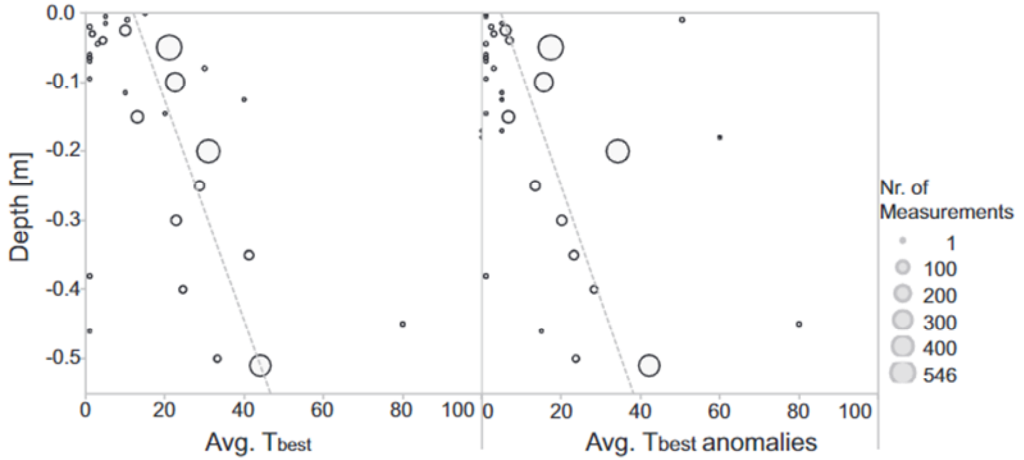
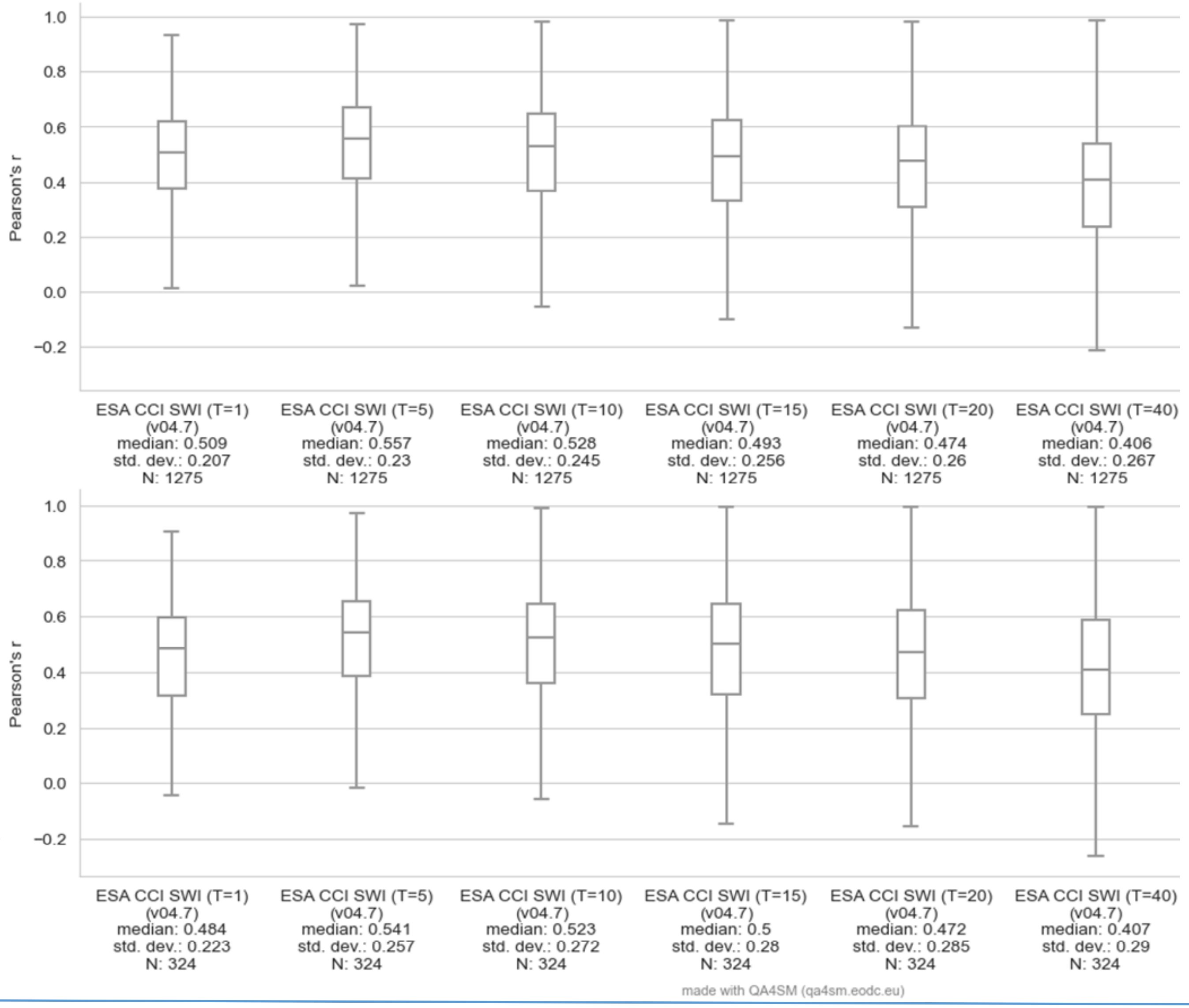


Fig.4. Average of T_{best} by depth of in situ observation. For original time series (left) and anomalies (right). Linear model fitted to avg. *T*values= -56.68 x medium depth + 11.04. *p*-Value: 0.028, R^2= 0.115. Linear model avg. *T*anomalies= -57.45 x medium depth + 4.03. *p*-Value: 0.0014, R^2= 0.229.

Correlation (Pearson's r) for a selection of SWI T-values and in-situ data reference data (ISMN_V20191211) for soil depth 0-5.1 cm (top) and 5.1-10 cm (bottom).



Outlook

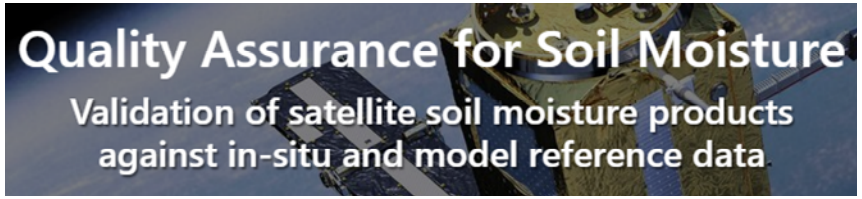
Within the G3P project we aim to develop a global gap-filled SWI product and describe the physical properties of *T*-values by exploring their relationship with a range soil characteristics. The latter was attempted in several studies so far with mixed results and merits further investigation. I.e., Paulik et al. (2014) and Albergel et al. (2008) did not find significant relationships between the parameter *T* and soil properties, while De Lange et al. (2008) obtained contrary results.

Acknowledgements and references

Soil Water Index is calculated from ESA CCI Soil Moisture COMBINED v04.7. Visit www.esa-soilmoisture-cci.org for more information and to access the data.

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

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



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