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A Multi-dimensional Accuracy Assessment and Development of ESI-based Water Stress Product of MSG-SEVIRI ET

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INTRODUCTION

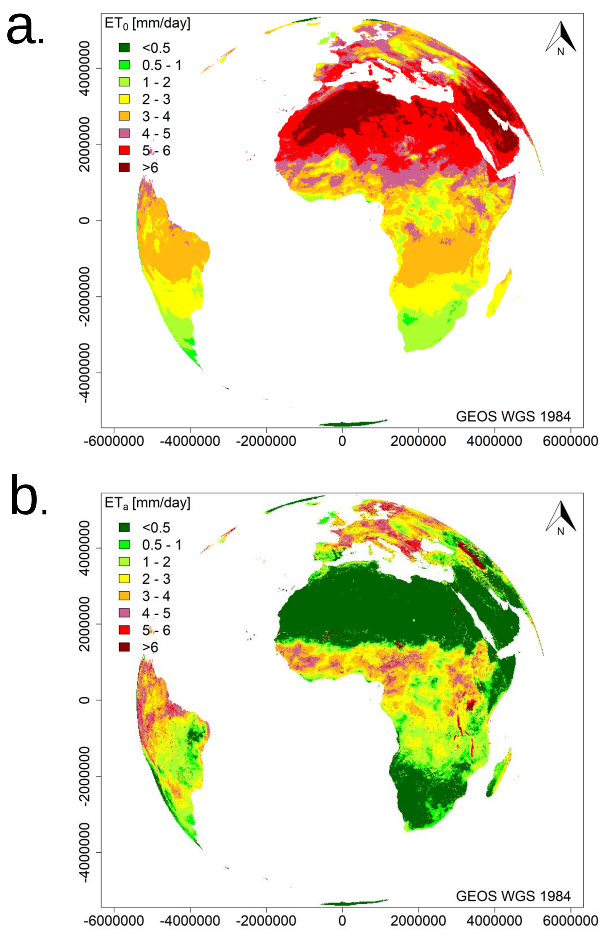
Remote sensing-based estimates of Evapotranspiration (ET) play a crucial role in detecting agricultural water stress. Operational ET products derived from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) sensor aboard the Meteosat Second Generation (MSG) satellites offer high temporal resolution and moderate spatial coverage, making them well-suited for water stress monitoring. Nonetheless, there remains a need for rigorous evaluation of SEVIRI observations and the development of streamlined workflows, ideally deployable on cloud-based platforms, to effectively utilize this data for large-scale water stress monitoring.

METHODS

- Separating the accuracy of SEVIRI-ET_a and SEVIRI-ET_0 [both from EUMETSAF LSA-SAF] into temporal (intra-annual and inter-annual) and spatial (ecosystem, ecoregion, and climate zones) dimensions across Europe between 2004 – 2018 (10825 daily images [i.e., 5413 SEVIRI-ET_0 and 5412 SEVIRI-ET_a]. In situ measurements were collected at 54 eddy covariance (EC) sites (Fig. 1c). KGE (Eq.4) and RMSE error metrics employed. KGE considers a balanced optimization of product bias, variability, and temporal fit to quantify the error efficiently. More details are presented in Bayat et al. (2024).

- Using SEVIRI-ET_a and SEVIRI-ET_0 products as an essential variable to quantify water stress levels in European countries based on Evaporative Stress Index (ESI) (Eq. 1 to 3) (Anderson et al., 2016).

- Establishing all process chains in a virtual laboratory [Vlab] (https://vlab.geodab.org/) on Amazon Web Services and implementing the workflow using Docker and GitHub technologies to gather baseline data to document initial conditions and map water stress status. More details are presented in Bayat et al. (2022).



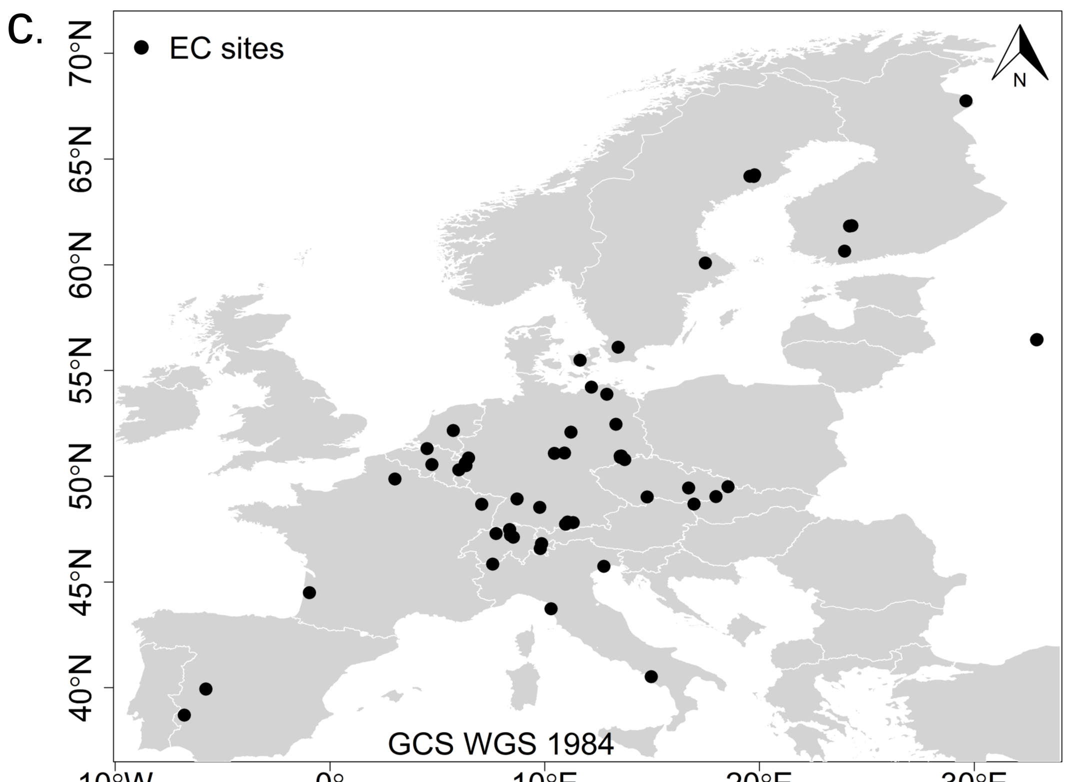


Figure 1. SEVIRI-ET_a (a) and SEVIRI-ET_0 (b) sample data set on 15 July 2018, and the spatial distribution of EC sites (c)

$$ESI = \frac{ETa}{ET0} \quad (1)$$

$$< ESI(d,y,i,j) > = \frac{1}{nc}\sum_{n=1}^{nc} < ESI(n,y,i,j) > \quad (2)$$

$$ESIA = \frac{<ESI(d,y,i,j)> - \frac{1}{ny}\sum_{y=1}^{ny} <ESI(d,y,i,j)>}{\sigma(d,i,j)} \quad (3)$$

ETa: Actual ET [mm/day]
ET0: Reference ET [mm/day]
ESI: Evaporative Stress Index [-]
ESIA: Evaporative Stress Index Anomalies [-]
d: daily time step,
y: year, i,j: grid location
nc: number of observations,
n: value of observation

$$KGE = 1 - \sqrt{(r-1)^2 + \left(\frac{\sigma_s}{\sigma_g} - 1\right)^2 + \left(\frac{\mu_s}{\mu_g} - 1\right)^2} \quad (4)$$

r: is the linear correlation between two dataset,
σ_s: the standard deviation in satellite,
σ_g: the standard deviation in in situ,
μ_s: the satellite mean,
μ_g: the ground mean.
The ratios σ_s/σ_g and μ_s/μ_g describe the variability error and the bias term

RESULTS

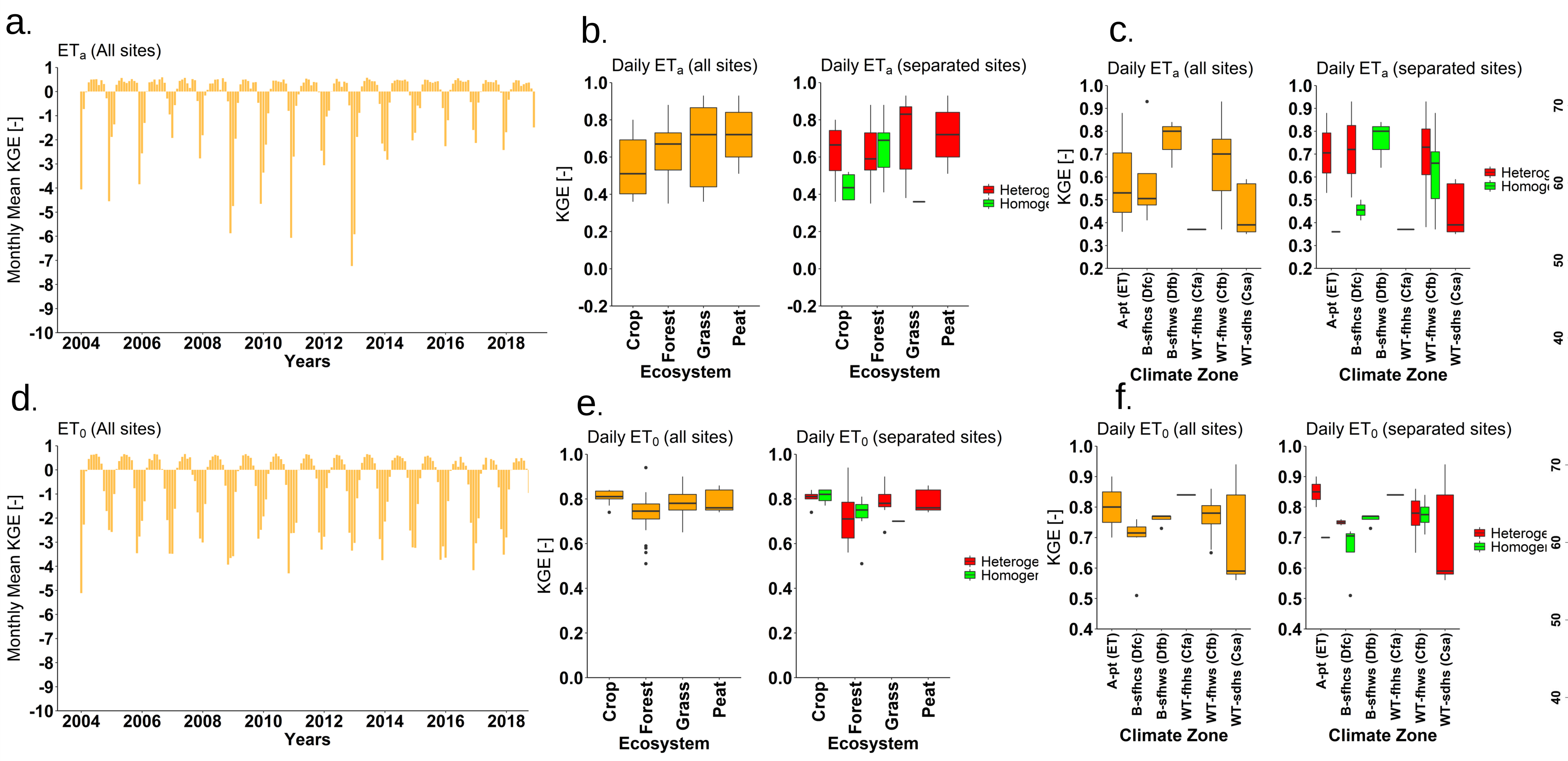


Figure 2. SEVIRI-ET_a (top panels) and SEVIRI-ET_0 (bottom panels) accuracies for intra-annual (a & d), ecosystem (b & e) and climate zone (c & f) dimensions considering all and separated (i.e., heterogeneous and homogeneous) sites.

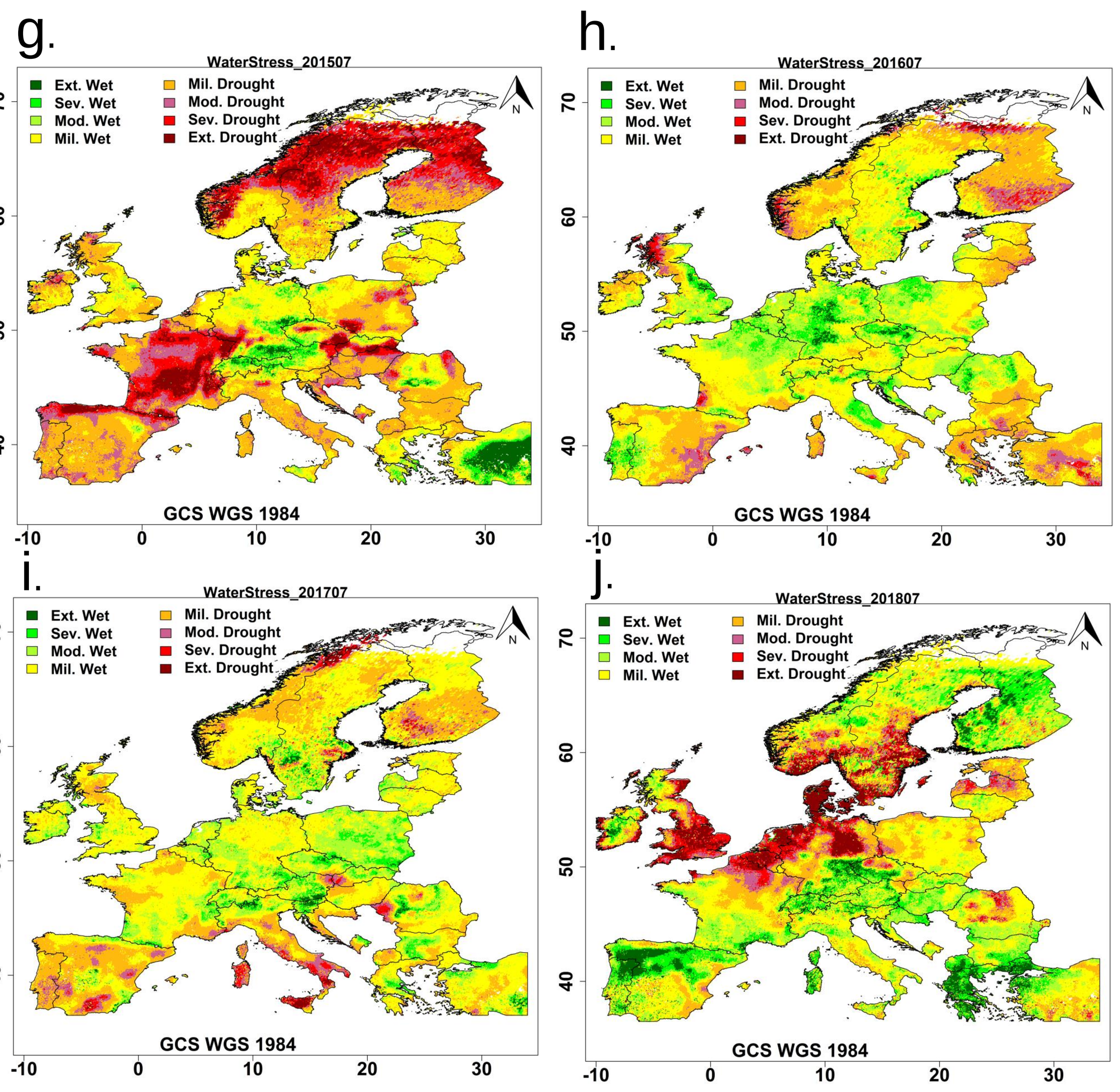


Figure 3. Representative examples of water stress maps generated from SEVIRI data for the month of July across Europe in 2015 (g), 2016 (h), 2017 (i) and 2018 (j)

DISCUSSION & CONCLUSIONS

- Fair agreement was achieved for SEVIR-ET and in situ ET in spatial (ecosystem and climate) dimensions.

- For SEVIRI-ET, intra-annual accuracy was low from January to March, increased in the mid-year, and then began to decline from November to December.

- Evaporative Stress Index (ESI) anomalies can be used in operational applications to quantify various water stress levels.

OUTLOOK

- Evaluation of SEVIRI observations at sub-daily scale can provide additional information. We intend to extend this study and analyze the accuracy of sub-daily SEVIRI-ET observations.

- Ecosystems, ecoregions and climatic zones responses to water stress can be explored and quantified from the water stress maps produced in this study.

KEY REFERENCES

• Anderson, M.C., Zolin, C.A., Sentelhas, P.C., Hain, C.R., Semmens, K., Tugrul Yilmaz, M., Gao, F., Otkin, J.A., Tetrault, R., 2016. The Evaporative Stress Index as an indicator of agricultural drought in Brazil: An assessment based on crop yield impacts. *Remote Sensing of Environment*. 174, 82–99.

• Bayat, B., Montzka, C., Graf, A., Giuliani, G., Santoro, M., Vereecken, H., 2022. One decade (2011-2020) of European agricultural water stress monitoring by MSG-SEVIRI: Workflow implementation on the Virtual Earth Laboratory (VLab) platform. *Int. J. Digital Earth*. https://doi.org/10.1080/17538947.2022.2061617.

• Bayat, B., Raj, R., Graf, A., Vereecken, H., Montzka, C., 2024. Comprehensive accuracy assessment of long-term geostationary SEVIRI-MSG evapotranspiration estimates across Europe, *Remote Sensing of Environment*, 301, 113875. https://doi.org/10.1016/j.rse.2023.113875