ESA-MOST Dragon Cooperation
2023 Dragon 5 Symposium

AGRICULTURAL WATER STRESS MONITORING BY MSG-SEVIRI ET OBSERVATIONS ACROSS EUROPE: A COMPREHENSIVE ACCURACY ASSESSMENT AND AN ESI-BASED WATER STRESS PRODUCT

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INTRODUCTION

Quantifying water stress levels in a simple, operational and straightforward way is of great importance, and urgently needed, not only for farmers, policy and decision makers but also for the scientific community. ET products derived from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) sensor onboard the Meteosat Second Generation (MSG) satellites make it a suitable candidate for water stress monitoring.
However, dedicated efforts are still required to evaluate the accuracy of SEVIRI observations and develop simple workflows, preferably executable on cloud-based platforms, to exploit its information content for water stress monitoring at larger scales.

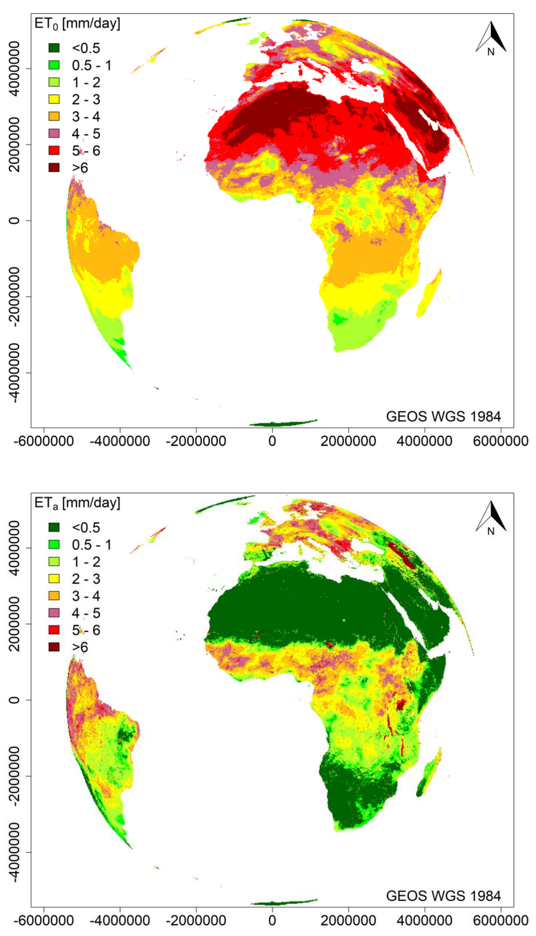
METHODS

- 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 (Gupta et al., 2009).

- 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 (Bayat et al. 2022).

a.
b.



c.

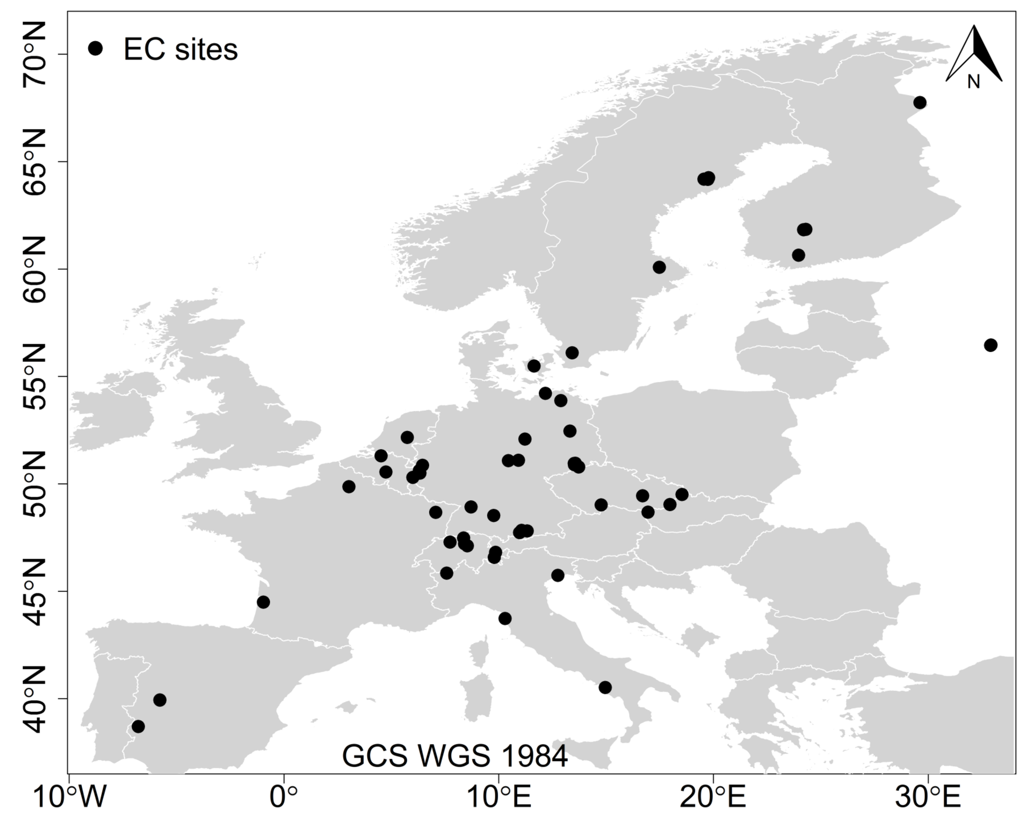


Figure 1. SEVIRI-ET_a (a) and SEVIRI-ET_0 (b) sample data set on 15 July 2018, and the spatial distribution of EC sites (c)

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

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

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

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

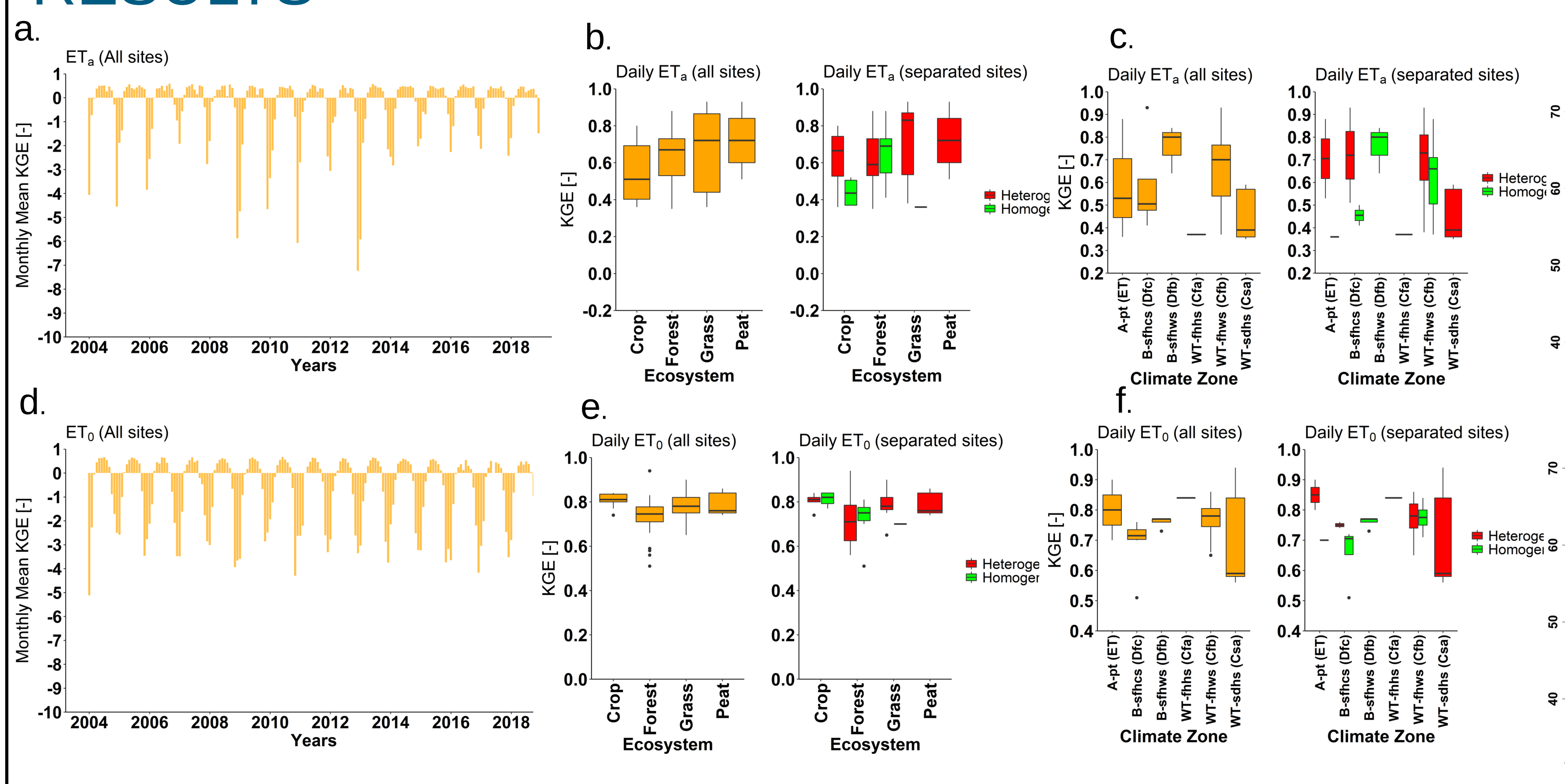


Figure 2. SEVIRI-ET_a (top panels) and SEVIRI-ET_0 (bottom panels) accuracies for intra-annual (a & d), ecosystem (b & e) and climate zone (c & f) dimensions considering all and separated (i.e., heterogeneous and homogeneous) sites.

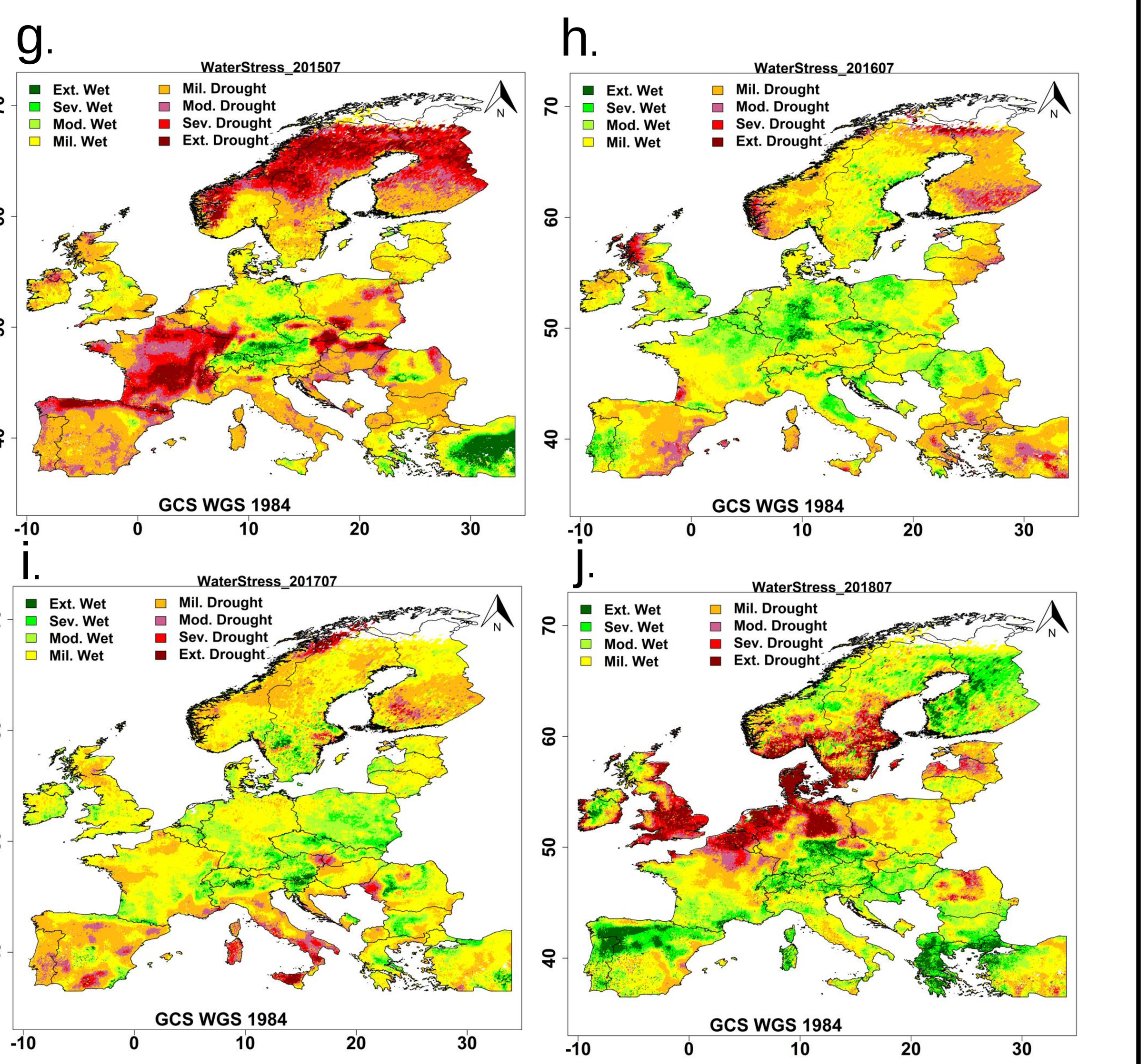


Figure 3. Representative examples of water stress maps generated from SEVIRI data for the month of July across Europe in 2015 (g), 2016 (h), 2017 (i) and 2018 (j)

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 Sens. Environ. 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. Digit. Earth. https://doi.org/10.1080/17538947.2022.2061617.
• Gupta, H. V, Kling, H., Yilmaz, K.K., Martinez, G.F., 2009. Decomposition of the mean squared error and NSE performance criteria: Implications for improving hydrological modelling. J. Hydrol. 377, 80–91. https://doi.org/https://doi.org/10.1016/j.jhydrol.2009.08.003