Supplementary materials for

Evaluating a multitask LSTM-based soil moisture model on the global scale for current and emerging threats to crops

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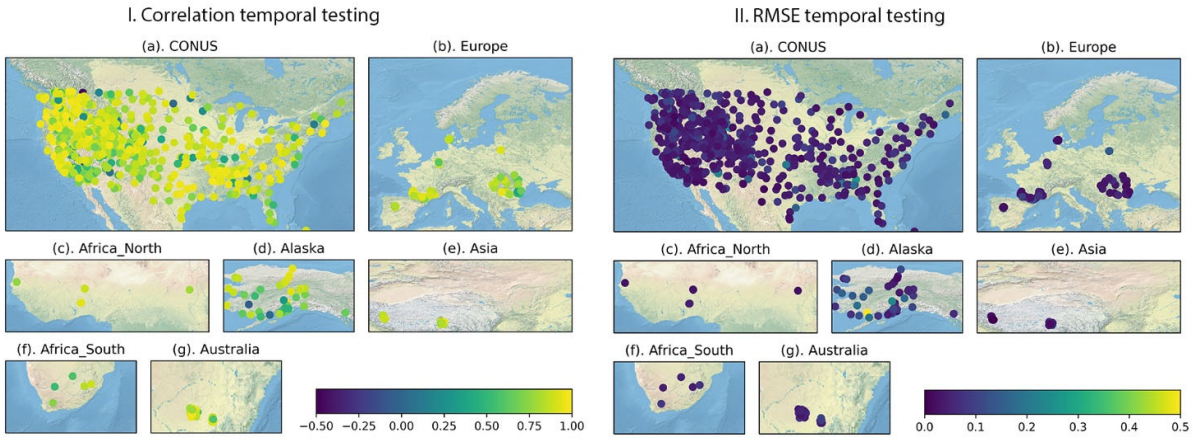

Fig. S1. Metric distributions for the multitask model temporal testing. (I.) Correlation and (II.) RMSE of temporal tests for (a) the CONUS, (b) Europe, (c) Africa_North, (d) Alaska, (e) Asia, (f) Africa_South, and (g) Australia. The training period is from April 1, 2016 to December 31, 2020 and the testing period is from April 1, 2015 to March 31, 2016. Maps are made with Natural Earth imagery, no permission needed (naturalearthdata.com).

Table S1. Description of data sets used for the multitask model

Data Name	Variables	Spatial-Temporal Resolution	Details
SMAP	soil moisture	9-km	SMAP Enhanced L3 Radiometer Global and Polar Grid Daily 9 km EASE-Grid Soil Moisture, Version 5
MCD43A3	albedo_BSA, albedo_WSA	500-m	Moderate Resolution Imaging Spectroradiometer (MODIS) MCD43A3 Version 6
MYD11A1	LST_Day, LST_Night	1-km	MODIS Land Surface Temperature/Emissivity Daily (MYD11A1) Version 6.1
ERA5	forecast_albedo, leaf_area_index_high_vegetation, leaf_area_index_low_vegetation, soil_temperature_level_, surface_pressure, surface_solar_radiation_downwards, temperature_2m, total_evaporation, u_component_of_wind_10m, v_component_of_wind_10m, volumetric_soil_water_layer_1, total_precipitation	0.1-degree	ERA5-Land Hourly - ECMWF Climate Reanalysis
GPM	precipitation	0.1-degree	Global Precipitation Measurement
MSWEP	precipitation	0.1-degree	Multi-Source Weighted-Ensemble Precipitation
Terrain attribution	slope, aspect, pcurv, aspectcosine, elevation, roughness	1-km	Global 1,5,10,100-km Topography database

Soil attribution	sand, clay, silt, texture, bulk density,	1:5 000 000	Harmonized world soil database v1.2 (HWSD)
Land cover	land cover	300-m	ESA CCI land cover 2018
Vegetation Indices	NDVI	0.05-degree	Vegetation Indices Monthly L3 Global 0.05Deg CMG

Table S2. The International Soil Moisture Network used in the model

Network	Country/ Region	website
AMMA-CATCH	Benin, Niger, Mali	http://www.amma-catch.org/
ARM	USA	http://www.arm.gov/
BIEBRZA_S-1	Poland	http://www.igik.edu.pl/en
CTP_SMTMN	China	http://dam.itpcas.ac.cn/rs/?q=data#CTP-SMTMN
DAHRA	Senegal	http://ign.ku.dk/earthobservation/research/document4/CaLM/
FLUXNET-AMERIFLUX	USA	http://ameriflux.lbl.gov/
FR_Aqui	France	no link available
HOBE	Denmark	http://www.hobe.dk/
NAQU	China	https://www.itc.nl/about-itc/organization/scientific-departments/water-resources/earth-observation-sites/tibetan-plateau-peoples-republic-of-china/
NGARI	China	https://www.itc.nl/about-itc/organization/scientific-departments/water-resources/earth-observation-sites/tibetan-plateau-peoples-republic-of-china/
OZNET	Australia	http://www.oznet.org.au/
PBO_H2O	USA	https://gnss-reflections.org/maps?product=smc
REMEDHUS	Spain	http://campus.usal.es/~hidrus/

RSMN	Romania	http://assimo.meteoromania.ro/
SCAN	USA	http://www.wcc.nrcs.usda.gov/
SD_DEM	Sudan	http://dx.doi.org/10.7167/2013/297973
SMN-SDR	China	https://doi.org/10.11888/Soil.tpdc.271425https://doi.org/10.11888/Soil.tpdc.271434
SMOSMANIA	France	http://www.hymex.org/
SNOTEL	USA	http://www.wcc.nrcs.usda.gov/
SOILSCAPE	USA	http://soilscape.usc.edu/
TAHMO	Côte d'Ivoire, Nigeria, Ghana, Uganda, Rwanda, Kenya	https://tahmo.org/
TERENO	Germany	http://teodoor.icg.kfa-juelich.de/overview-de
USCRN	USA	http://www.ncdc.noaa.gov/crn/

Table S3. Soil moisture estimated products are used for comparison, including three satellite productions, one land surface product, and one machine learning production.

Property	Product	Resolution
Low-frequency passive microwave product (L-band)	SMAP-L3	9-km
	SMOS-L3	25-km
High-frequency passive microwave product (X-band)	LPRM_AMSR2_DS_A_SOILM3	10-km
Land surface product	GLDAS_NOAH025	0.25°
Machine learning-based product	SoMO.ml	0.25°

Table S4. Comparison of multitask model's performance with other products on the global scale

	AMSR2	GLDAS	SMOS	SoMo.ML (train)	SMAP	Multitask LSTM (temporal test)	Multitask LSTM (spatial test)	Multitask LSTM (train)
Bias	0.080	0.257	-0.042	0.070	-0.010	0.001	-0.0003	0.003
RMSE	0.169	0.268	0.105	0.101	0.091	0.051	0.075	0.045
ubRMSE	0.141	0.060	0.080	0.047	0.062	0.043	0.056	0.039
Corr	0.379	0.699	0.548	0.805	0.621	0.837	0.792	0.853

Table S5. Performance of the model's temporal experiment using different precipitation productions

	Corr	RMSE	Bias	ubRMSE
ERA5	0.786	0.057	-0.008	0.047
GPM	0.805	0.055	-0.003	0.045
MSWEP	0.840	0.512	-0.001	0.042
MSWEP+GPM+ERA5	0.837	0.051	0.001	0.043