Supplement of Hydrol. Earth Syst. Sci., 25, 3713–3729, 2021
https://doi.org/10.5194/hess-25-3713-2021-supplement
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Hydrology and Earth System Sciences
Open Access

Supplement of

Drought onset and propagation into soil moisture and grassland vegetation responses during the 2012–2019 major drought in Southern California

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Supplementary Material

The supplementary material provides further information on soil textural properties, statistical results of data analysis, modeling concept and governing equations. Soil textural properties were collected in the field by Roberts et. al. (2010). A schematic overview of the modeling inputs and governing equations is provided for the soil moisture balance model used in the paper to give a more comprehensive overview of the structure.

S1 Soil textural properties

Soil samples of each site were collected in the field and soil textures analyzed in the lab, during site installation at COPR and AIRS by Roberts et al. (2010). We used these values in our SMBM and include them as a Monte Carlo variation to account for natural variability in soil properties (Table S1).

Site	Depth	Texture	% Sand	% Clay	% Silt	Porosity	FC	WP
COPR	10 cm	Clay Loam	28	30	42	0.71	0.4	0.13
	20 cm	Clay Loam	24	37	39	0.66	0.48	0.15
	50 cm	Clay Loam	24	36	40		0.47	0.22
AIRS	15 cm	Loam	39	17	44	0.34	0.28	0.07
	23 cm	Loam	38	16	45	0.39	0.3	0.07
	46 cm	Loam	39	17	45		0.28	0.07

[caption] Table S1: Soil textural properties for the coastal (COPR) and inland (AIRS) site. Soil samples were taken at the time of site installation and soil textural properties analyzed in the lab.

S2 Key parameters for the Soil Moisture Balance Model

Parameter	Definition	COPR	AIRS
Z_r [mm]	Rooting Depth	700 -1000mm (both)	
k_c [-]	Crop coefficient	From NDVI (both)	
θ_{FC} [m3/m3]	Field capacity	0.4-0.5	0.2-0.3
θ_{WP} [m3/m3]	Wilting point	0.1-0.2	0.001-0.05
Pc [-]	Depletion fraction for RAW	0.2-0.6 (both)	

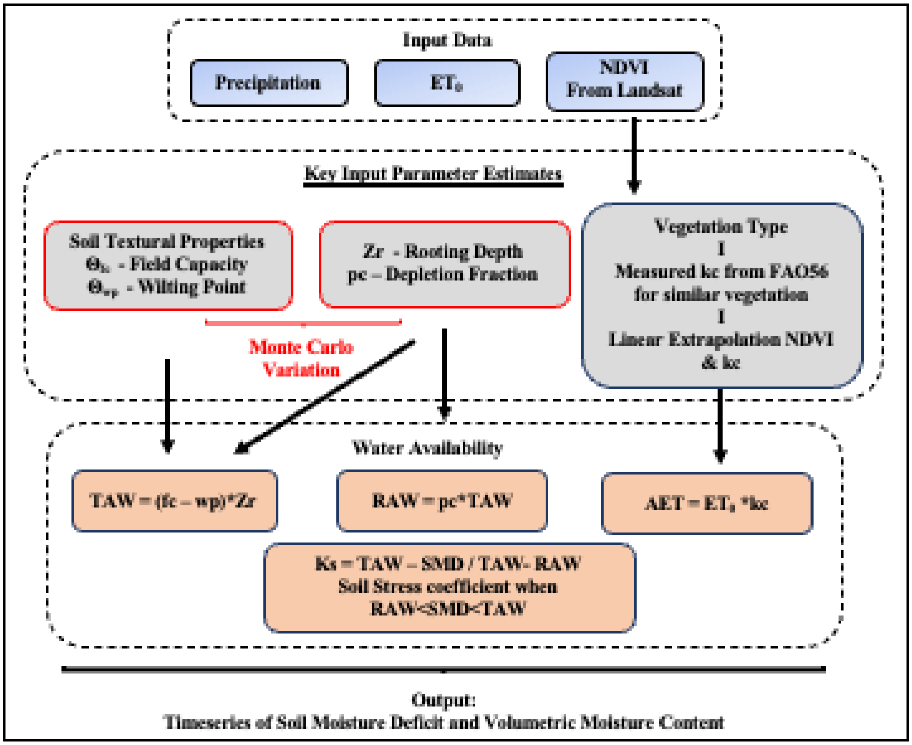
[caption] Table S2: Ranges of used key parameter values used as input for the SMBM. Rooting depth is an estimate, based on dominant vegetation type at the sites. Ranges for soil textural properties are from Table S1 in the supplementary material. Crop coefficients are derived from NDVI for both sites. The depletion fraction is based on a standard range used by the FAO (Allen et al., 1998).

S3 Model concept and governing equations

The model concept is illustrated in **Error! Reference source not found.**, including input data and key input parameter estimates. Water availability is defined through Total Available Water (TAW) and Readily Available Water (RAW). The model concept is illustrated in **Error! Reference source not found.**, including input data and key input parameter estimates. Water availability is defined through Total Available Water (TAW) and Readily Available Water (RAW). The model expresses water content as soil moisture deficit (SMD). At field capacity, the moisture deficit is zero. As water is lost through evapotranspiration, SMD increases and soil moisture stress is induced when SMD = RAW. If SMD > RAW, the moisture deficit is high enough to limit AET to less than maximum rate and AET starts to decrease relative to the remaining water in the root zone. If evaporative demands and moisture deficit can be met by precipitation, any remaining water is lost through drainage. Initial depletion (SMDi-1) can be estimated from measured soil water content through:

$$SMD_{i-1} = 1000 * (\theta_{fc} - \theta_{i-1}) * Z_r$$

where θi-1 is the average soil water content for the effective root zone. More detailed information can be found in Chapter 8 of Allen et.al. (1998).



[caption] Figure S1: SMBM concept including input data and key parameter estimates, which can be based on field measurements or estimates. The model includes a Monte Carlo variation to account for variability in parameter estimates.

S4 Statistical Parameters for Climate Data Analysis

Statistical significances of climate parameters are shown in Table S3.

Site	**Variable**	**ND-MD**		**ND-ED**		**MD-ED**	
		Statistic	Sign.	Statistic	Sign.	Statistic	Sign.
Coastal	AT	0.14	**0.001**	0.21	**0.001**	0.12	**0.001**
	RH	0.05	0.21	0.05	**0.05**	0.03	0.38
	ET_0	0.06	**0.05**	0.03	0.39	0.07	**0.001**
	P	0.30	0.06	0.36	**0.01**	0.12	0.77
	NDVI	0.30	**0.001**	0.32	**0.001**	0.22	**0.001**
	Saturation	0.25	0.17	0.45	**0.001**	0.34	**0.01**
	aP	0.47	0.001	0.55	**0.001**	0.26	**0.05**

Inland	AT	0.05	0.06	0.08	**0.001**	0.06	**0.01**
	RH	0.11	**0.001**	0.1	**0.001**	0.03	0.46
	ET_0	0.08	**0.001**	0.04	**0.05**	0.05	0.065
	P	0.18	0.45	0.16	0.51	0.09	0.96
	NDVI	0.19	**0.001**	0.18	**0.001**	0.11	**0.001**
	Saturation	0.25	0.16	0.36	**0.01**	0.25	**0.05**
	aP	0.25	0.15	0.29	**0.05**	0.20	0.20

[caption]Table S3: Statistical significance of climate parameters as measured by Pearsons correlation. Significance levels are noted at the 0.05, 0.01 and 0.001 level.

S5 Regression of NDVI with aP (formerly Figure 7)

Linear regression analysis was used to establish a relationship between NDVI and aP for the coastal and inland sites, using historic data for the entire study period. This relationship was used to create a leading indicator to estimate NDVI under different climate scenarios.

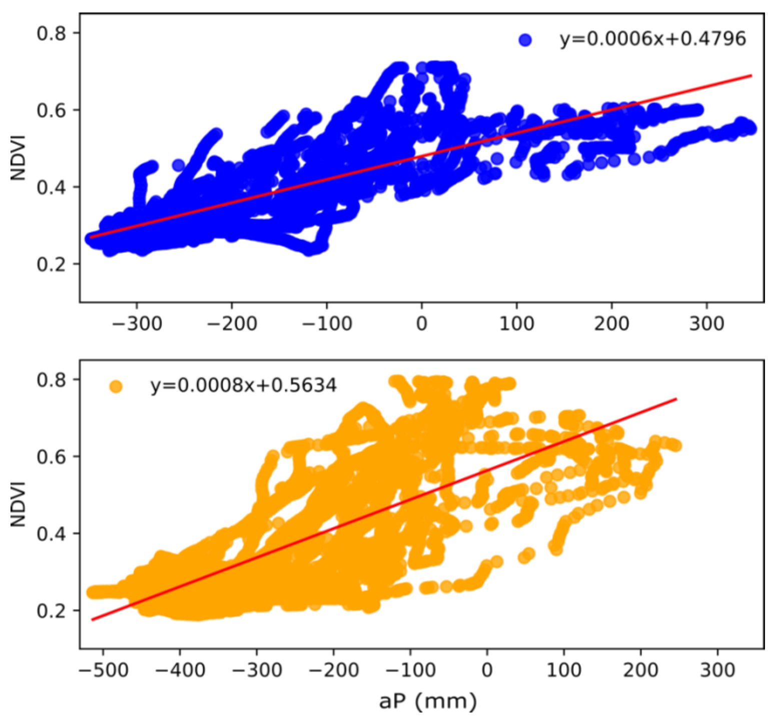


Figure S2: Regression between NDVI and aP for the coastal (blue) and inland (orange) site.