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Drought-related Impacts and the Role of Soil Moisture Feedback in Africa

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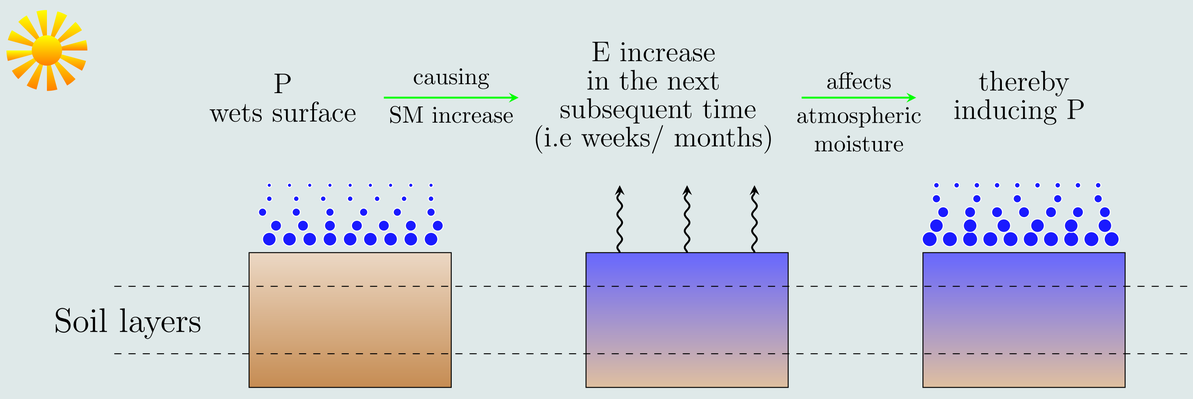
Abstract

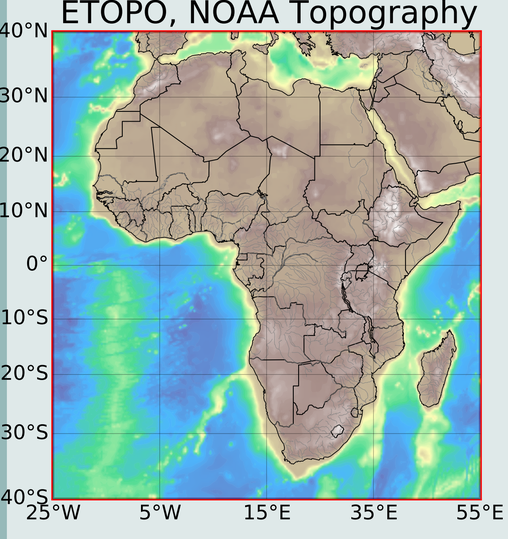
Global warming presents profound challenges to global freshwater and food security, with a particular focus on Africa. This study investigates the impact of changing water availability, calculated as the difference between precipitation (P), evapotranspiration (E), along soil moisture (SM), on water resources and wet-dry conditions. The analysis employs the Standardized Precipitation-Evapotranspiration Index (SPEI) and Vapor Pressure Deficit (VPD), utilizing reanalysis data, satellite observations, and regional climate models to assess SM-(P-E) over 1-month lag of 1981-2005 and under the RCP8.5 climate scenario. The findings illuminate the intricate interplay between SM and P-E, especially in the context of a drier climate anticipated post-2080, while also revealing seasonal variations in the correlation between VPD and SM.

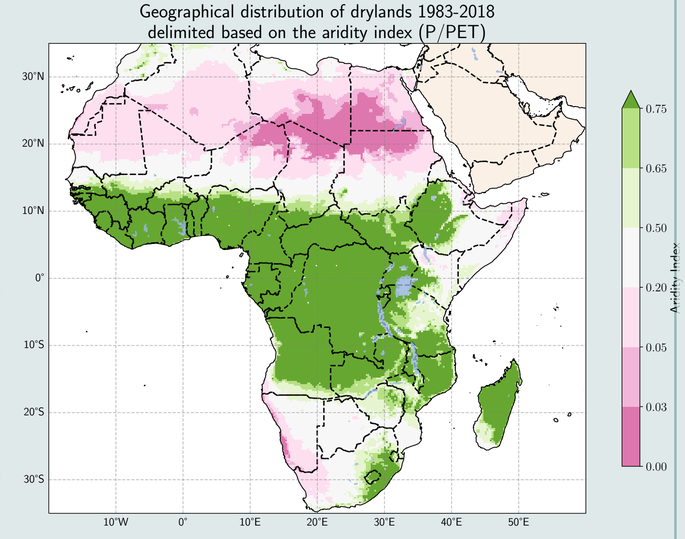
Introduction and Region of study



SM feedbacks, in which the amount of water on the land surface exerts a limitation on E, thereby influencing the amount of energy and water that are returned to the atmosphere. Where SM is projected to decrease, temperature extremes increase due to this trend (Ruth Lorenz et. al, 2015), which refers to the extended effects of drought on agricultural systems and meteorological conditions.

"Will droughts in East Africa become more common?" UK Centre of Ecology & Hydrology



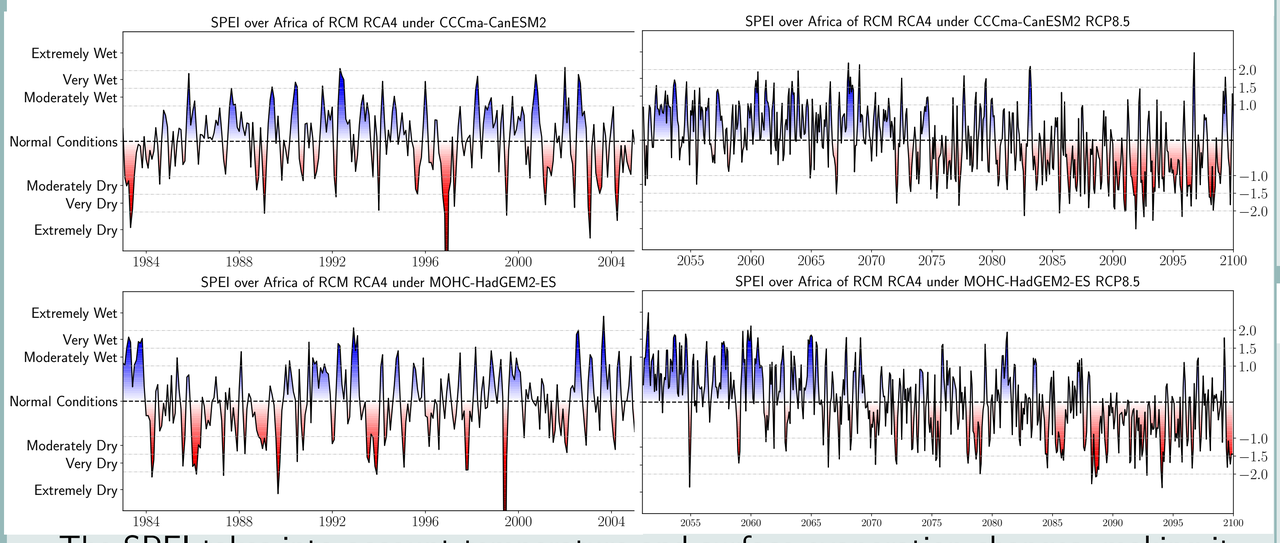


Currently data use

Type	Name		Spatial grid	Period	Variables
Satellite-based product	GLEAM		0.25x0.25	1981-2005, monthly 1983-2005, monthly	Evapotranspiration Soil moisture
	TAMSAT				Precipitation
Reanalysis	Era5-Land		0.1x0.1	1981-2005, monthly	Precipitation Evapotranspiration 10m u-wind 10m v-wind Soil moisture* Specific humidity* Relative humidity Air temperature
RCMs (CORDEX) Domain: AFR-44	RCA4	CCCma-CanESM2 MOHC-HadGEM2-ES	0.44x0.44	1981-2005 2051-2100, monthly under RCP8.5	
	REMO2009	IPSL-IPSL-CMA5-LR MIROC-MIROC5			

*calculated from other dependent variables.

SPEI classification in historical period and under RCP8.5 projections of RC4



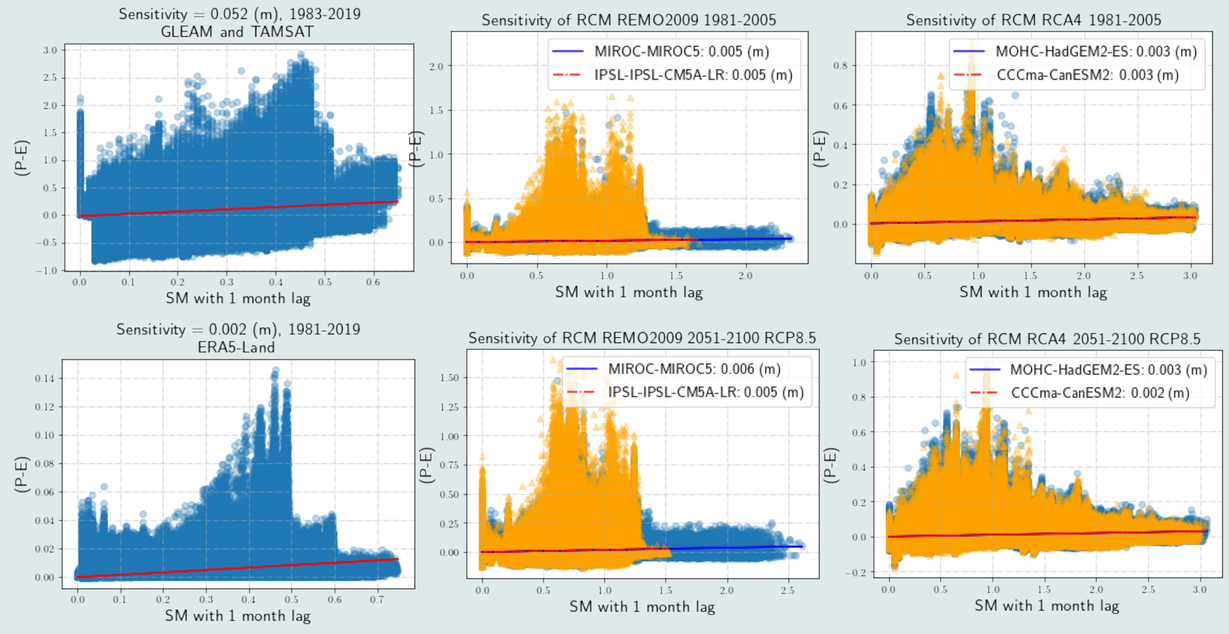
The SPEI takes into account temperature and surface evaporation changes, making it more sensitive to drought. It suggests a transition to wetter conditions up to around 2075, followed by a shift towards drier conditions from about 2080 onwards.

Feedbacks

A multiple linear regression model between (P-E) and one-month lagged SM to assess the SM-(P-E) feedback:

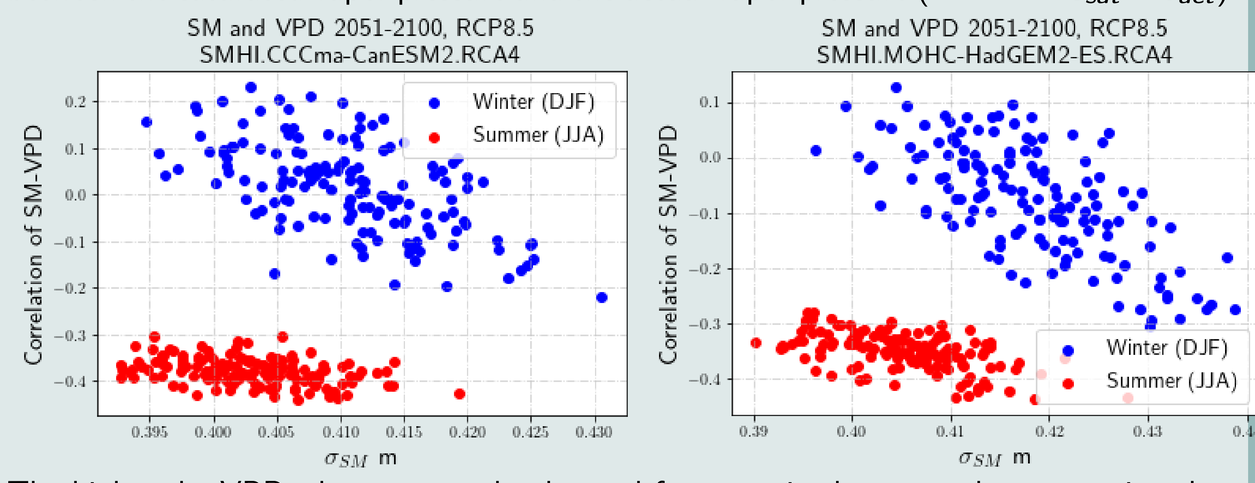
$$(P-E)_d(t+1) = n_0 + n_1.SM_d(t) + n_2.(P-E)_d(t)$$

- $n_2.(P-E)_d(t)$ aims to remove the effect of (P-E) autocorrelation; d indicates the multi-year mean seasonal cycle.
- The regression coefficient obtained from the linear model reflects the long-term mean effect of SM on P-E.
- n_1 *is expected to obtain using partial least square regression (PLSR), which combines principal component analysis and multiple linear regression techniques.*



Vapor Pressure Deficit (VPD)-SM under RCP8.5 projections of RC4

VPD is a measure of the atmospheric demand (or atmospheric "thirst") for water and is a variable tightly related to evapotranspiration. Specifically, VPD is the difference between the saturated vapor pressure and the actual vapor pressure ($VPD = e_{sat} - e_{act}$)



The higher the VPD, the stronger the demand for water in the atmosphere, meaning the air is capable of holding much more water vapor than it currently contains. As a result, SM tends to lose water rapidly. This creates a negative correlation between SM and VPD. The faster water loss from the soil during summer may indicate reduced variability in soil moisture content during the summer months.

Discussions

Feasibility and uncertainties (models and scenarios) when using multiple models and datasets will be emphasized in the near future because they can directly affect the signal of feedback. The project is still in the development and completion stage, besides, some SM sources will also be evaluated such as Mean Flow Convergent and Transient Eddy Convergence.

Conclusions

In the near future, REMO2009 and RCA4 both demonstrate that the amount of feedback sensitivity is nearly unchanged compared to the previous time of 0.005 and 0.003 m between SM and (P-E). However, SPEI has revealed a more precise alteration in the duration and magnitude of RCM RCA4's dry condition. It suggests that comprehending these land-atmosphere interactions and their responses to climate change remains challenging and requires special attention when tackling upcoming water shortage concerns, particularly in regions prone to extended droughts.

References

[1] Marc Alessi, Dimitris Herrera, Colin Evans, et. al. Soil moisture conditions determine landatmosphere coupling and drought risk in the northeastern united states. Journal of Geophysical Research Atmospheres, 127, 03 2022.

[2] Paul Palmer, Caroline Wainwright, Bo Dong, Ross Maidment, et al. Drivers and impacts of eastern african rainfall variability. Nature Reviews Earth Environment, 4, 03 2023.

[3] Jitendra Singh, Moetasim Ashfaq, Christopher Skinner, et al. Amplified risk of spatially compounding droughts during co-occurrences of modes of natural ocean variability. npj Climate and Atmospheric Science, 4, 02 2021.

[4] Jiangfeng Wei, Hua Su, and Zong-Liang Yang. Impact of moisture flux convergence and soil moisture on precipitation: A case study for the southern united states with implications for the globe. Climate Dynamics, 46, 04 2015.

[5] Sha Zhou, Alton Williams, Ben Lintner, Alexis Berg, Yao Zhang, Trevor Keenan, Benjamin Cook, Stefan Hagemann, Sonia Seneviratne, and Pierre Gentine. Soil moisture–atmosphere feedbacks mitigate declining water availability in drylands. Nature Climate Change, 11, 01 2021.