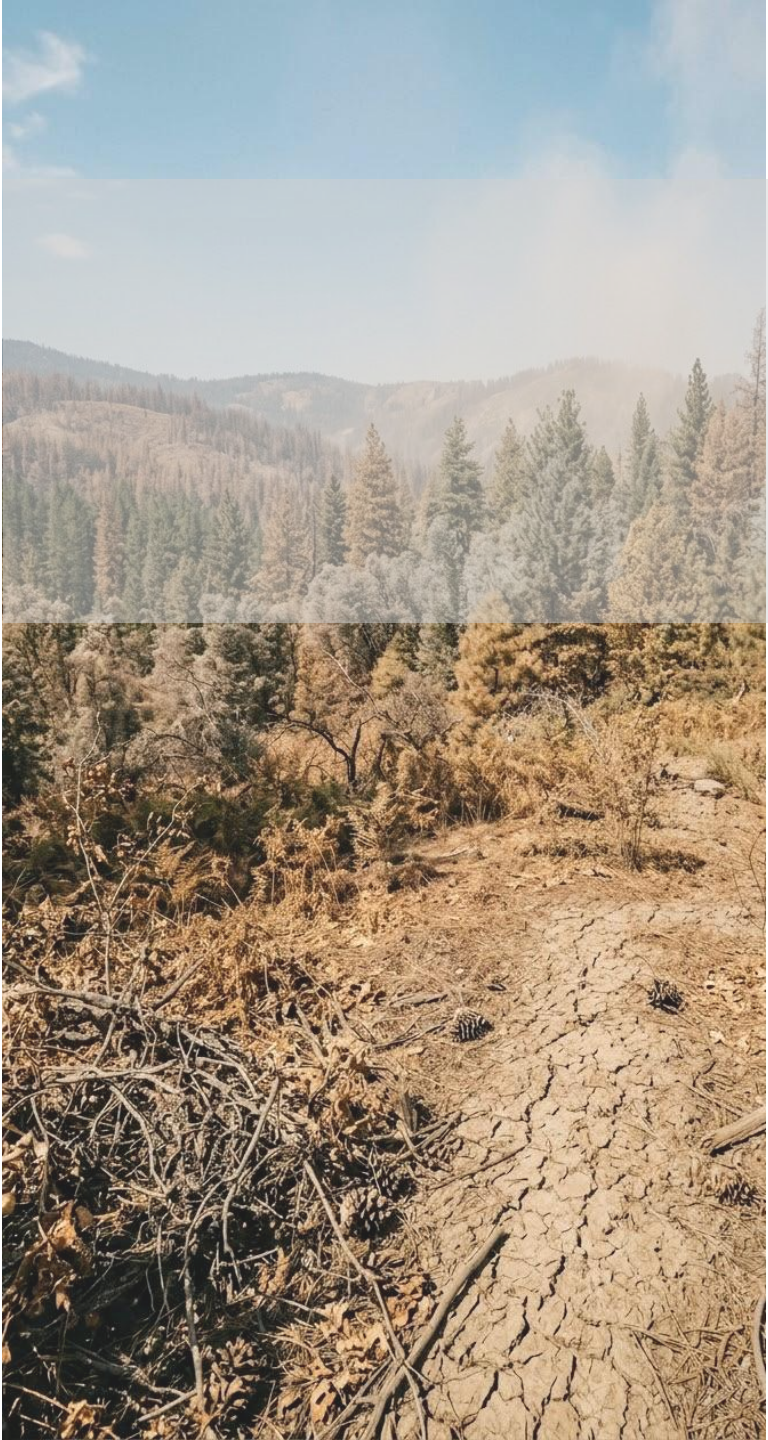




Enhancing flash drought prediction by quantifying vegetation responses to rainfall and heatwave pulses

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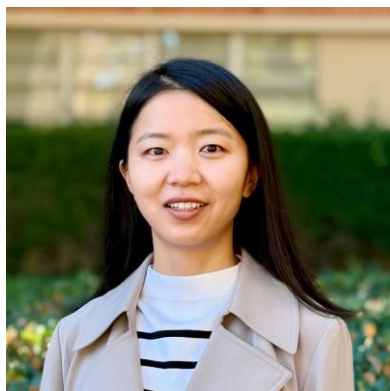
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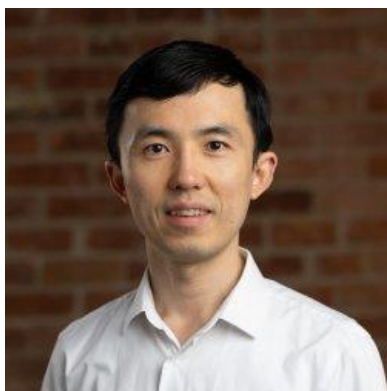
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Project team



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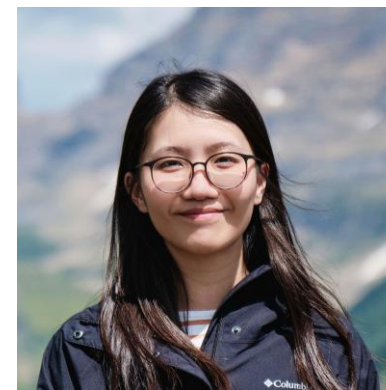
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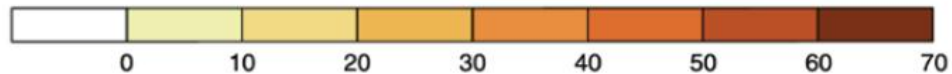
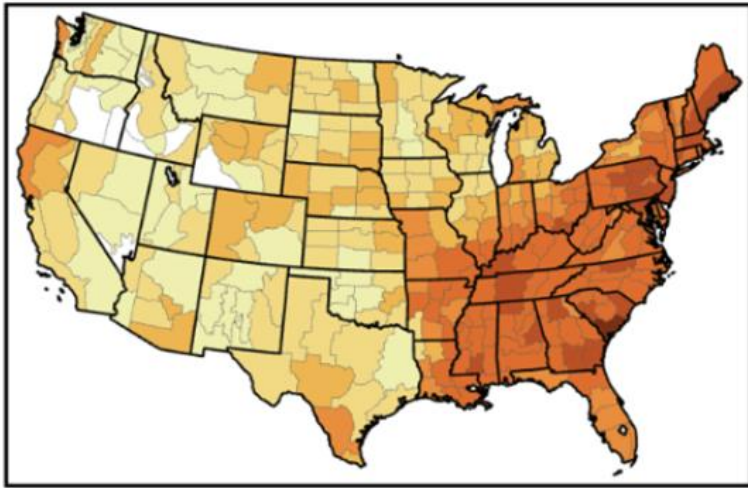
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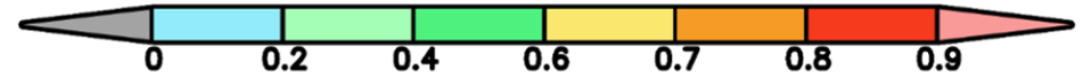
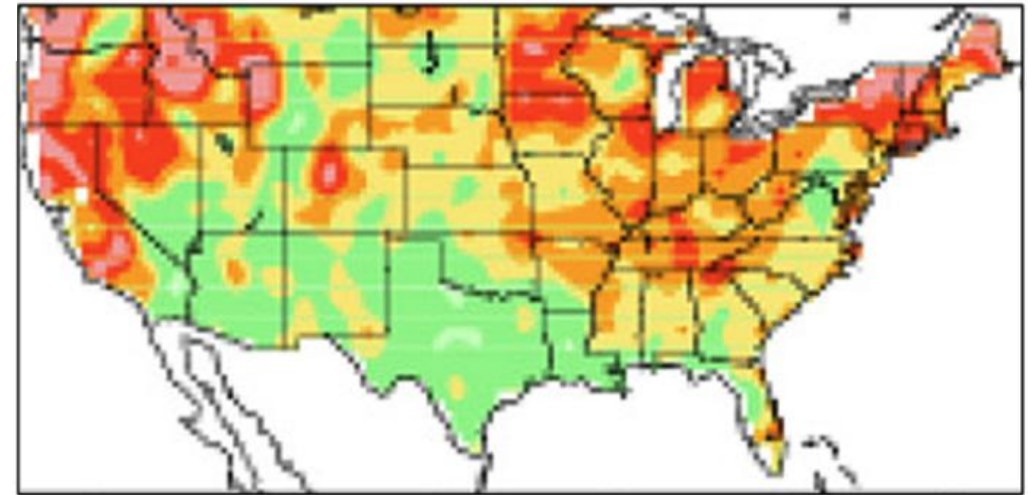
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Background

- Flash droughts unfold quickly, within weeks to months.
- Flash droughts frequently occur in the U.S. but remain challenging to predict.
- Beyond climate oscillations, they are also affected by land-atmosphere interactions.



Flash drought frequency over 100 years



False alarm rate of 5-day flash drought forecasts

(Pendergrass et al., Nat., Clim. Chang., 2020; Mo and Lettenmaier, J. Hydrometeorol., 2020)

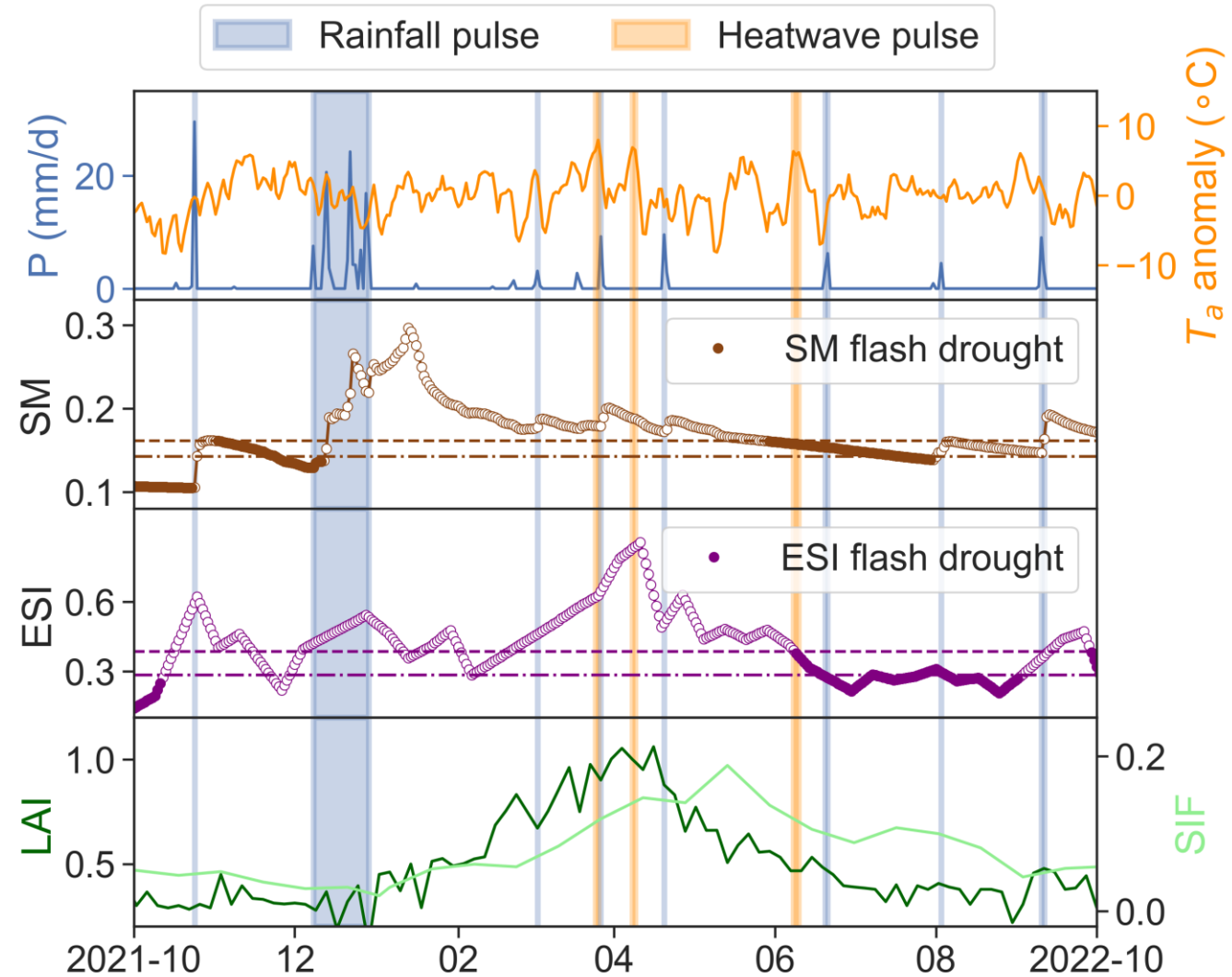
Overall goal

Mechanistically quantify the ecohydrological dynamics within soil plant atmosphere system (SPAS) co-regulated by vegetation and the physical climate, and to elucidate their roles in driving flash droughts.

Overall hypothesis

Vegetation dynamics following pulses are a key determinant of flash drought initiation and intensification, and mechanistic characterization of vegetation feedback can improve flash drought predictability.

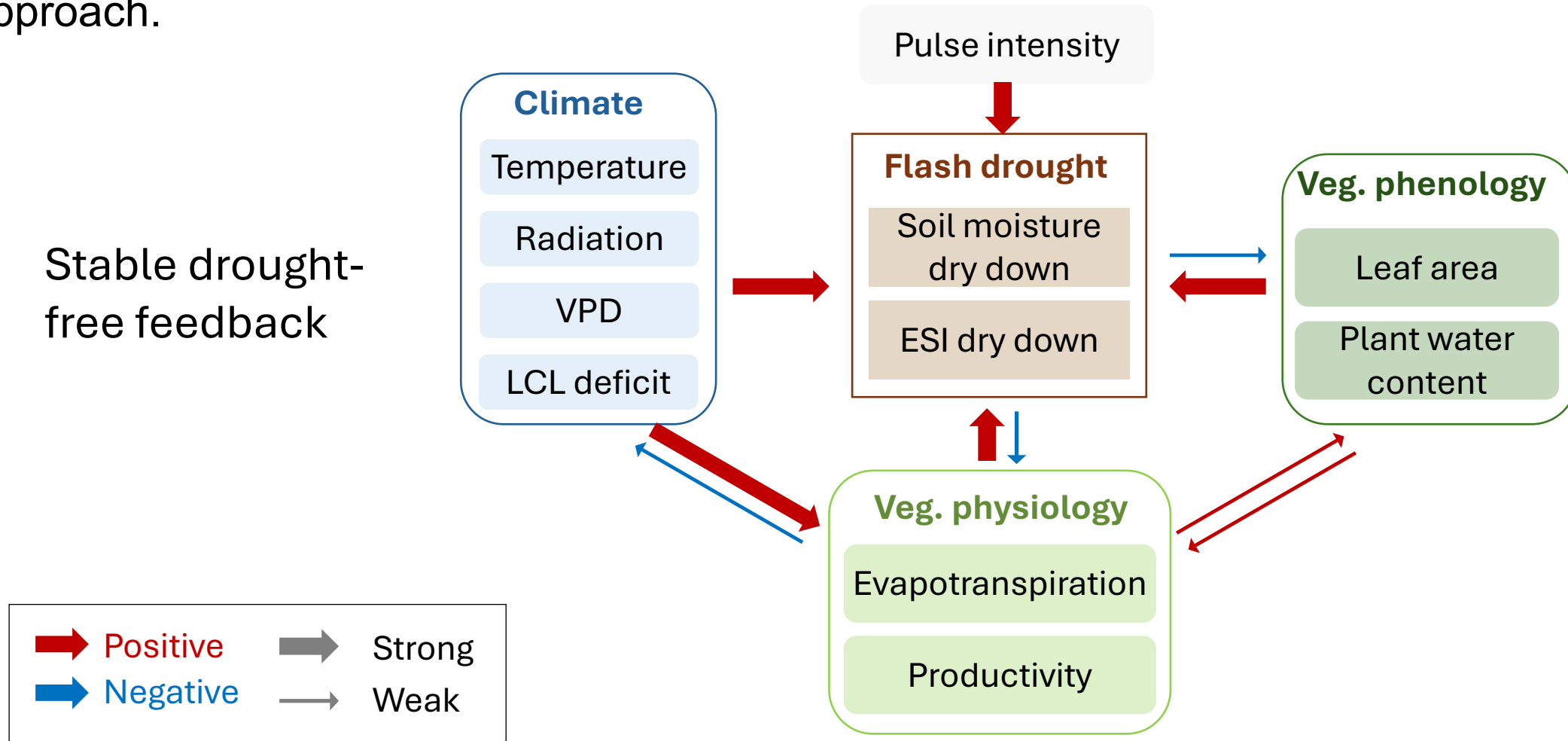
An example of dry-downs and flash droughts



Soil moisture (SM); Evaporative stress index (ESI = ET/PET)

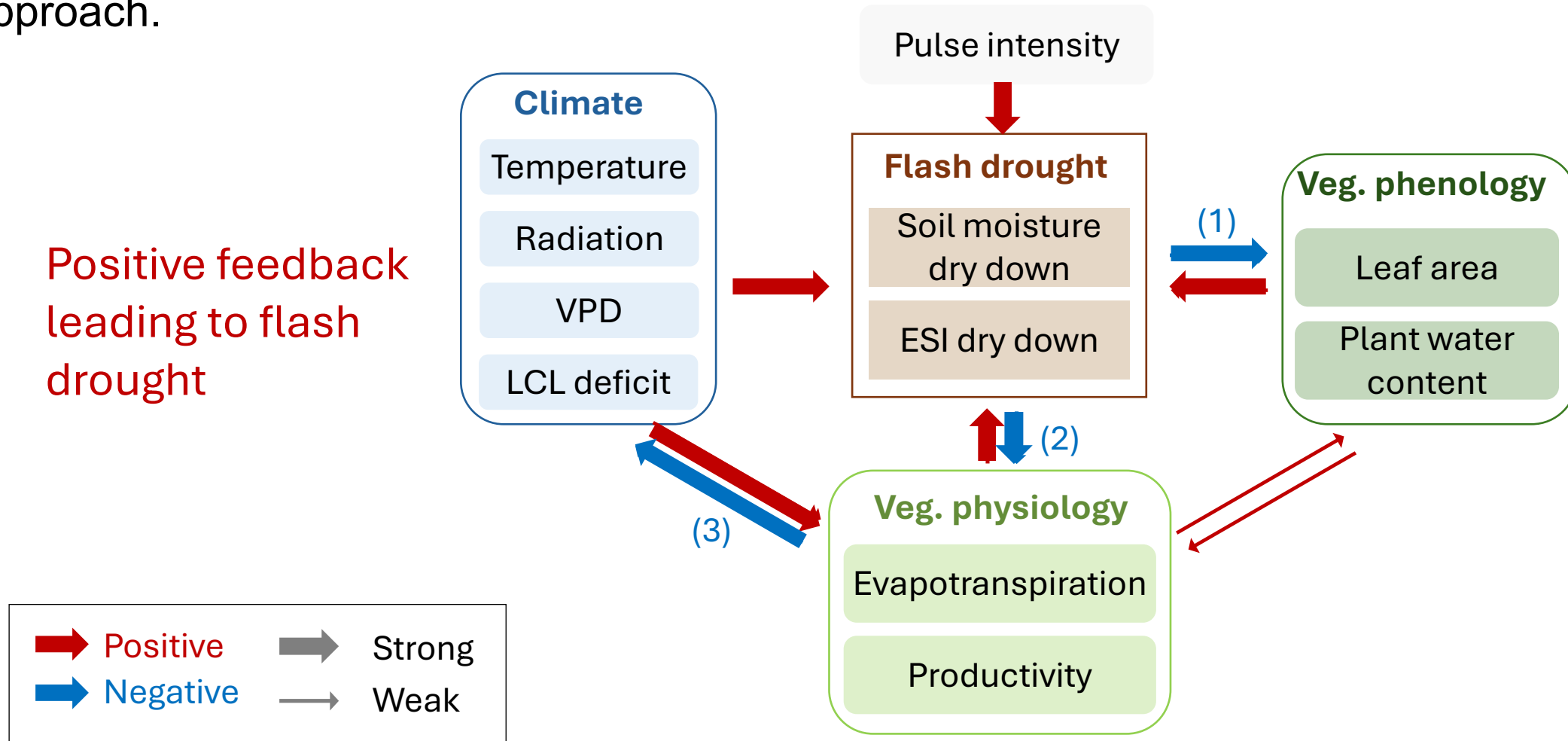
Objective 1: Causality detection

Detect causal relationships among observed vegetation dynamics, climate conditions, and flash drought indicators across diverse biomes and climate gradients using a data-driven approach.



Objective 1: Causality detection

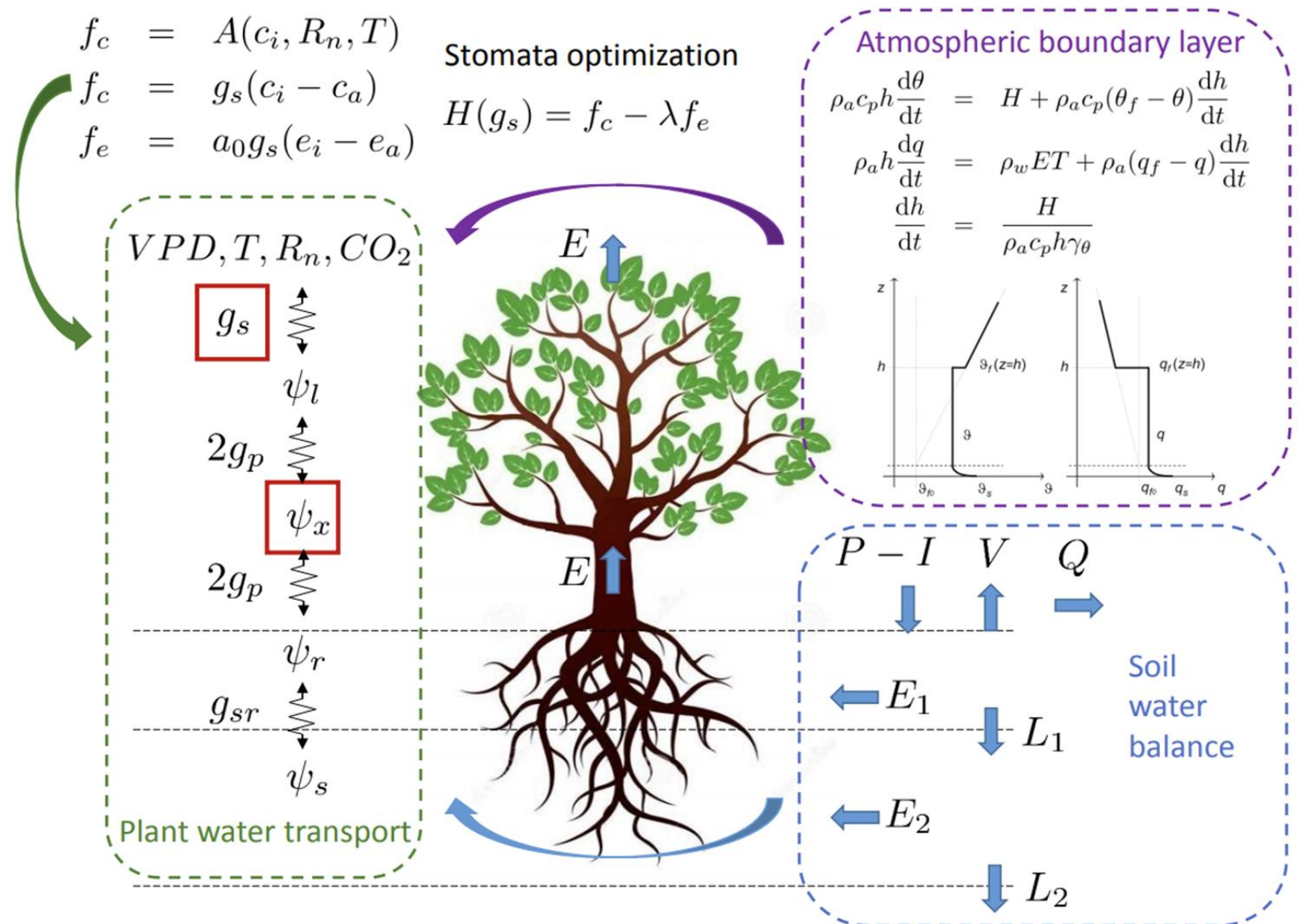
Detect causal relationships among observed vegetation dynamics, climate conditions, and flash drought indicators across diverse biomes and climate gradients using a data-driven approach.



Objective 2: Mechanism diagnostics

Diagnose the mechanistic pathways within the soil–plant–atmosphere system (SPAS) that drive flash drought initiation and intensification, using a SPAS model, aligned with Noah-MP-PHS and constrained by ground and remote sensing observations.

(Liu et al., 2017; 2020; 2021; Bai et al. 2021; Tan et al, in review)



Objective 2: Mechanism diagnostics

Table 2 | Experimental design of using SPAS to diagnose mechanisms and data assimilation for flash drought prediction. The “+” denotes a representation is turned on or a dataset is assimilated. Shaded cells highlight the targeted mechanism and data to be tested in each experiment.

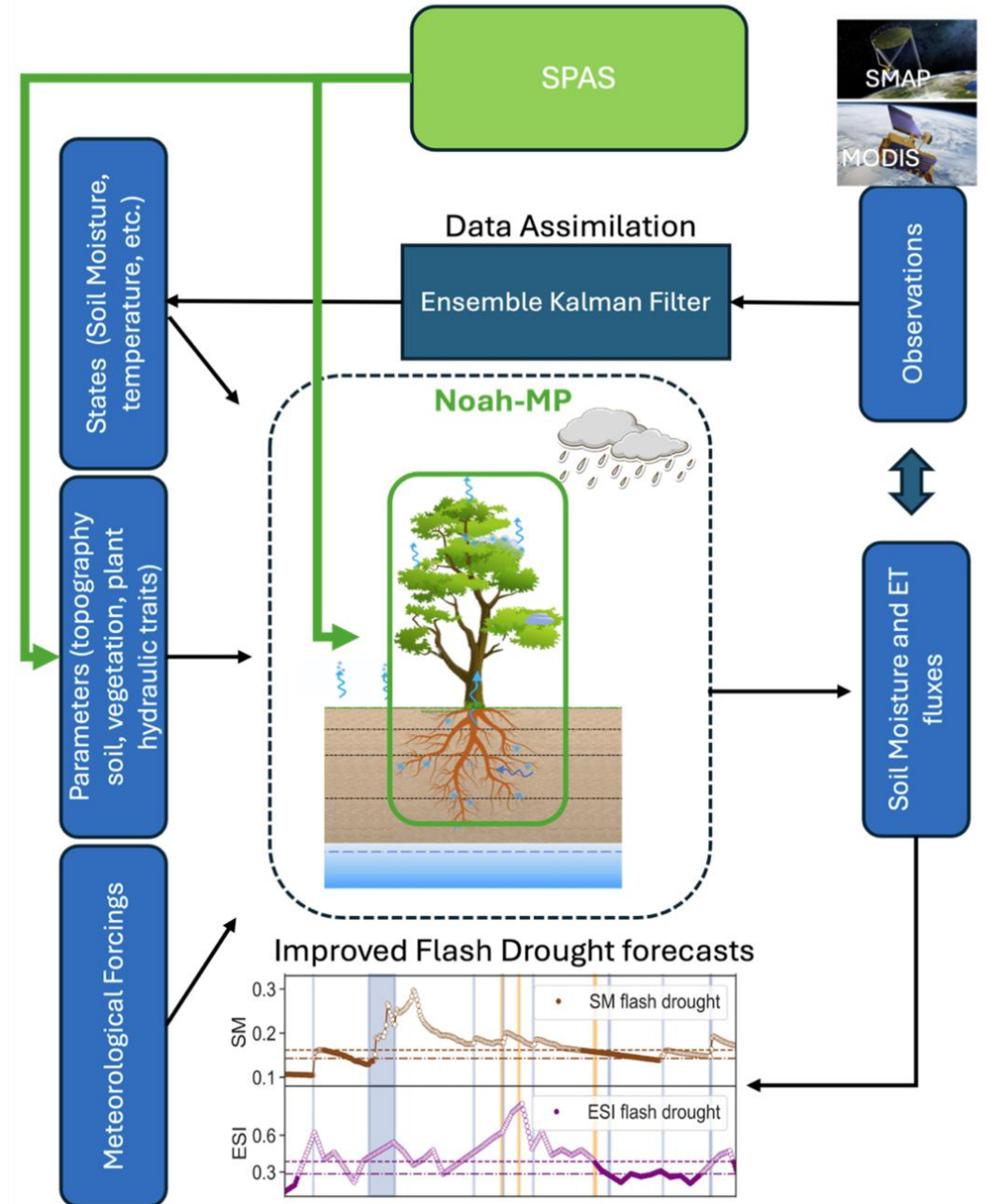
Goal	Exp.	Mechanistic representations			Data assimilation		
		Plant hydraulics	Soil structure	Atm. coupling	LAI	Init. SM	Init. VOD
Mechanism diagnostics	1	+	+	+	+		
	2		+	+	+		
	3	+		+	+		
	4	+	+		+		
Assimilation of initial conditions	5	+	+				
	6	+	+		+		
	7	+	+		+	+	
	8	+	+		+	+	+

Additionally test assimilating EVI and NDWI (water stress) shared by MODIS and PACE, and new PACE hyperspectral indices, including PRI (light-use efficiency) and CIRE (phenology) to build IMVI-aligned capacity for future prediction..

Objective 3: Flash drought prediction

Enhance flash drought prediction by improving process representation, parameterization, and data assimilation within the land surface model Noah-MP-PHS.

- Implement prioritized data assimilation strategies and optimized parameterization established through Objectives 1 and 2
- Leverage the existing data assimilation infrastructure and capabilities of NASA's Land Information System.



Deliverables

- **An observation-based benchmark** quantifying the direction, strength, and spatiotemporal variability of causal links between vegetation dynamics and flash drought.
- **A mechanistic model–data fusion framework** that constrains the SPAS model with ground and remote sensing observations to diagnose vegetation feedback mechanisms and identify observations most useful for improving flash drought prediction.
- **A continental-scale modeling toolkit** built on Noah-MP and LIS to improve flash drought prediction across the contiguous U.S., supporting flash drought preparedness and mitigation.

Thank you!

