

Evaluating the relative influence of soil water potential, soil moisture, and vapor pressure deficit on semi-arid vegetation dynamics

Kayla Jamerson



5 year cooperative agreement
with MCO (L16AC00359)



Committee Members: Kelsey G. Jencso, Zachary H. Hoylman, Anna Sala, Ashley Ballantyne



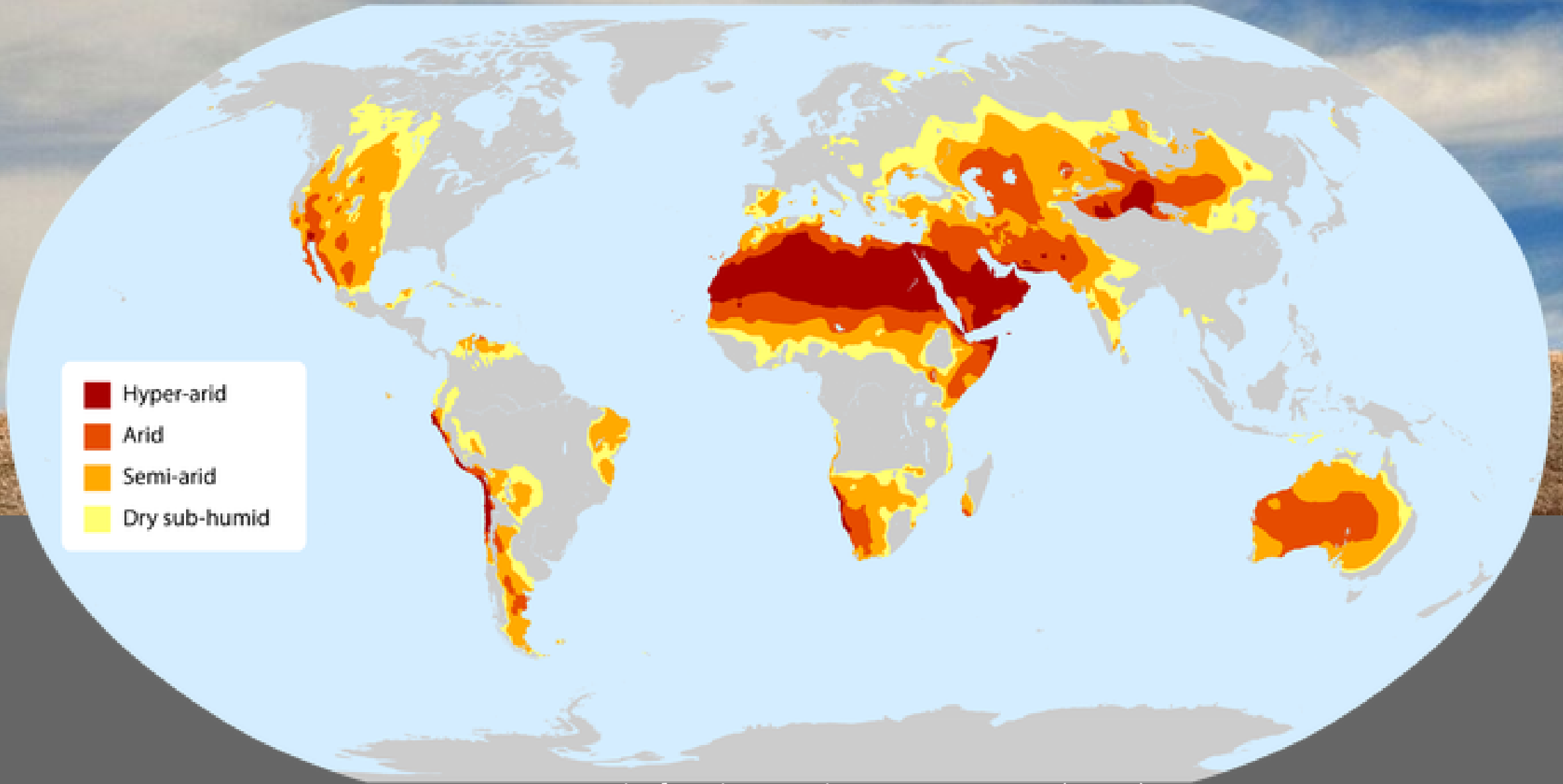


Image Source: United Nations Environment Program (UNEP)

How does vegetation respond to droughts?

Water Potential Gradient

Atmosphere
-100 Mpa

Leaf
-7.0 Mpa

Xylem
-2.5 Mpa

Root
-1.0 Mpa

Soil
-0.5 Mpa

nature climate change

[Explore content](#) [About the journal](#) [Publish with us](#)

[nature](#) > [nature climate change](#) > [letters](#) > article

Published: 05 September 2016

The increasing importance of atmospheric demand for ecosystem water and carbon fluxes

[Kimberly A. Novick](#) [Darren L. Ficklin](#), [Paul C. Stoy](#), [Christopher A. Williams](#), [Gil Bohrer](#), [A. Christopher Oishi](#), [Shirley A. Papuga](#), [Peter D. Blanken](#), [Asko Noormets](#), [Benjamin N. Sulman](#), [Russell L. Scott](#), [Lixin Wang](#) & [Richard P. Phillips](#)

nature

[Explore content](#) [About the journal](#) [Publish with us](#)

[nature](#) > [letters](#) > article

Published: 21 October 2010

Recent decline in the global land evapotranspiration trend due to limited moisture supply

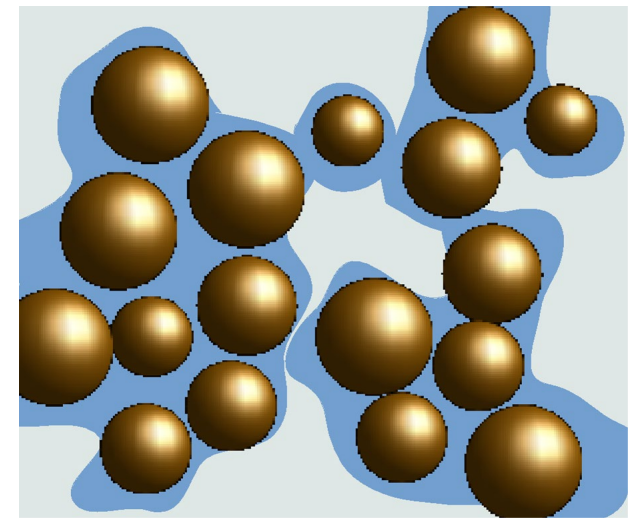
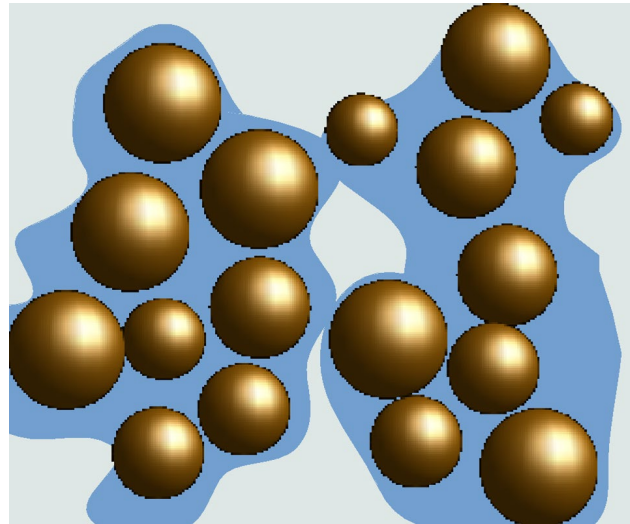
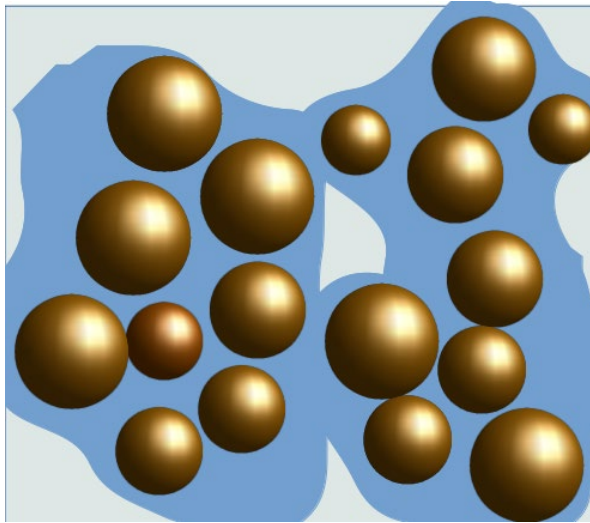
[Martin Jung](#) [Markus Reichstein](#), [Philippe Ciais](#), [Sonia I. Seneviratne](#), [Justin Sheffield](#), [Michael L. Goulden](#), [Gordon Bonan](#), [Alessandro Cescatti](#), [Jiquan Chen](#), [Richard de Jeu](#), [A. Johannes Dolman](#), [Werner Eugster](#), [Dieter Gerten](#), [Damiano Gianelle](#), [Nadine Gobron](#), [Jens Heinke](#), [John Kimball](#), [Beverly E. Law](#), [Leonardo Montagnani](#), [Qiaozhen Mu](#), [Brigitte Mueller](#), [Keith Oleson](#), [Dario Papale](#), [Andrew D.](#)

Atmosphere

Plant

Soil

Soil water potential



More water



Less water

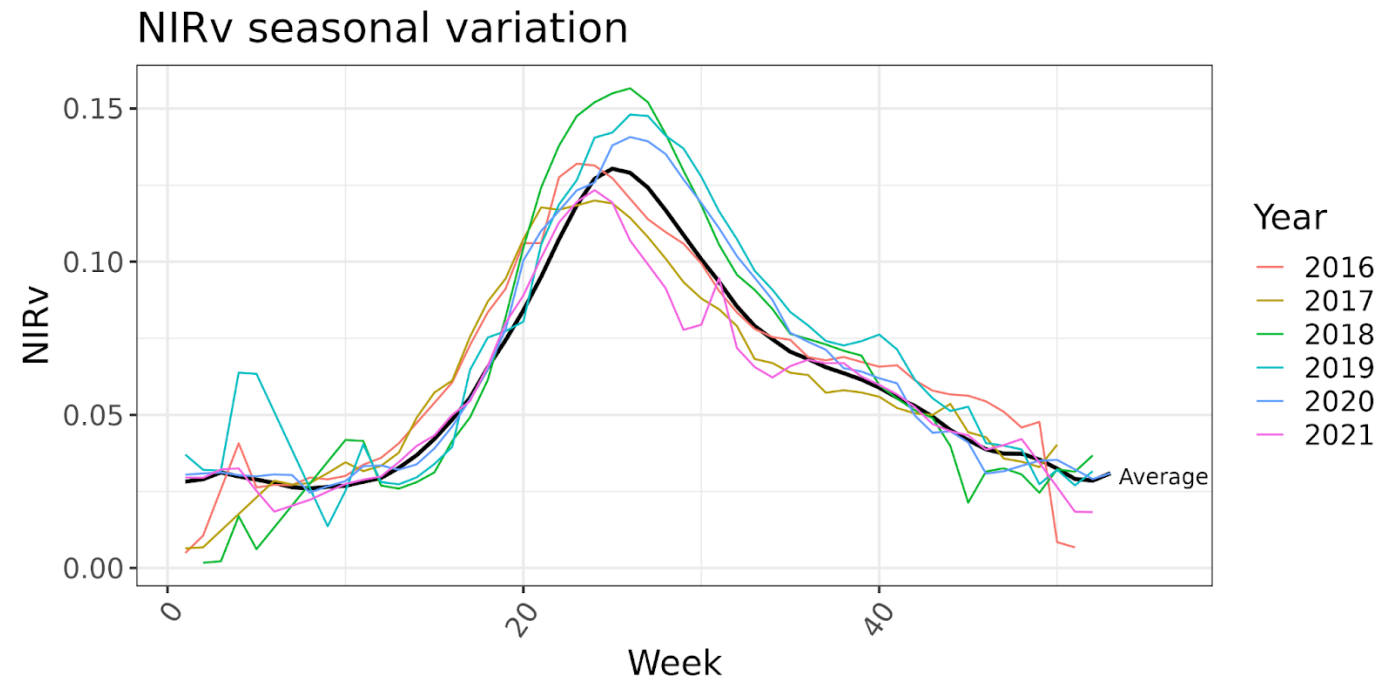
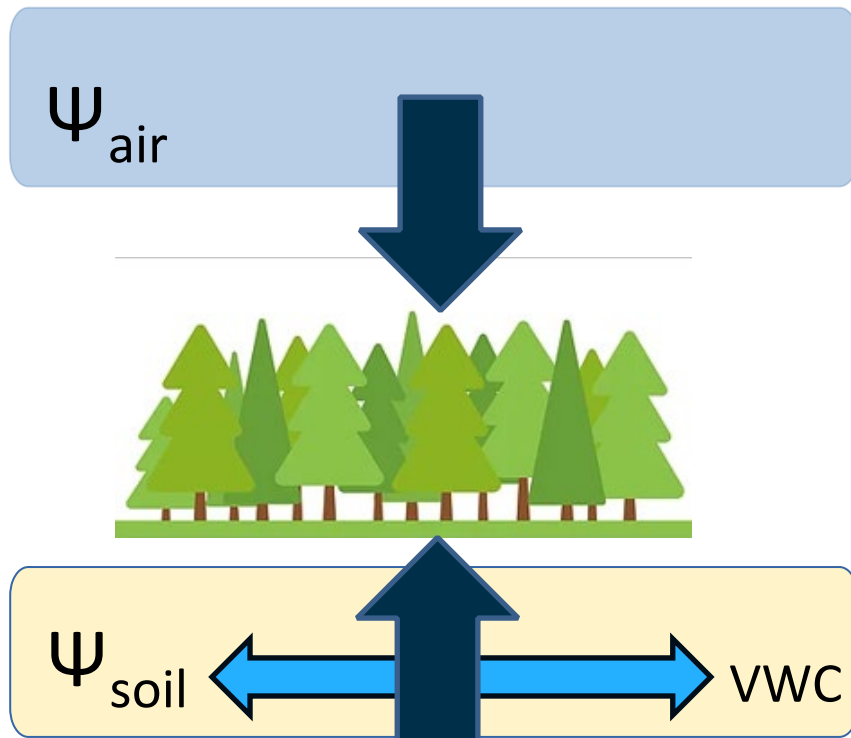
Soil

Research Questions

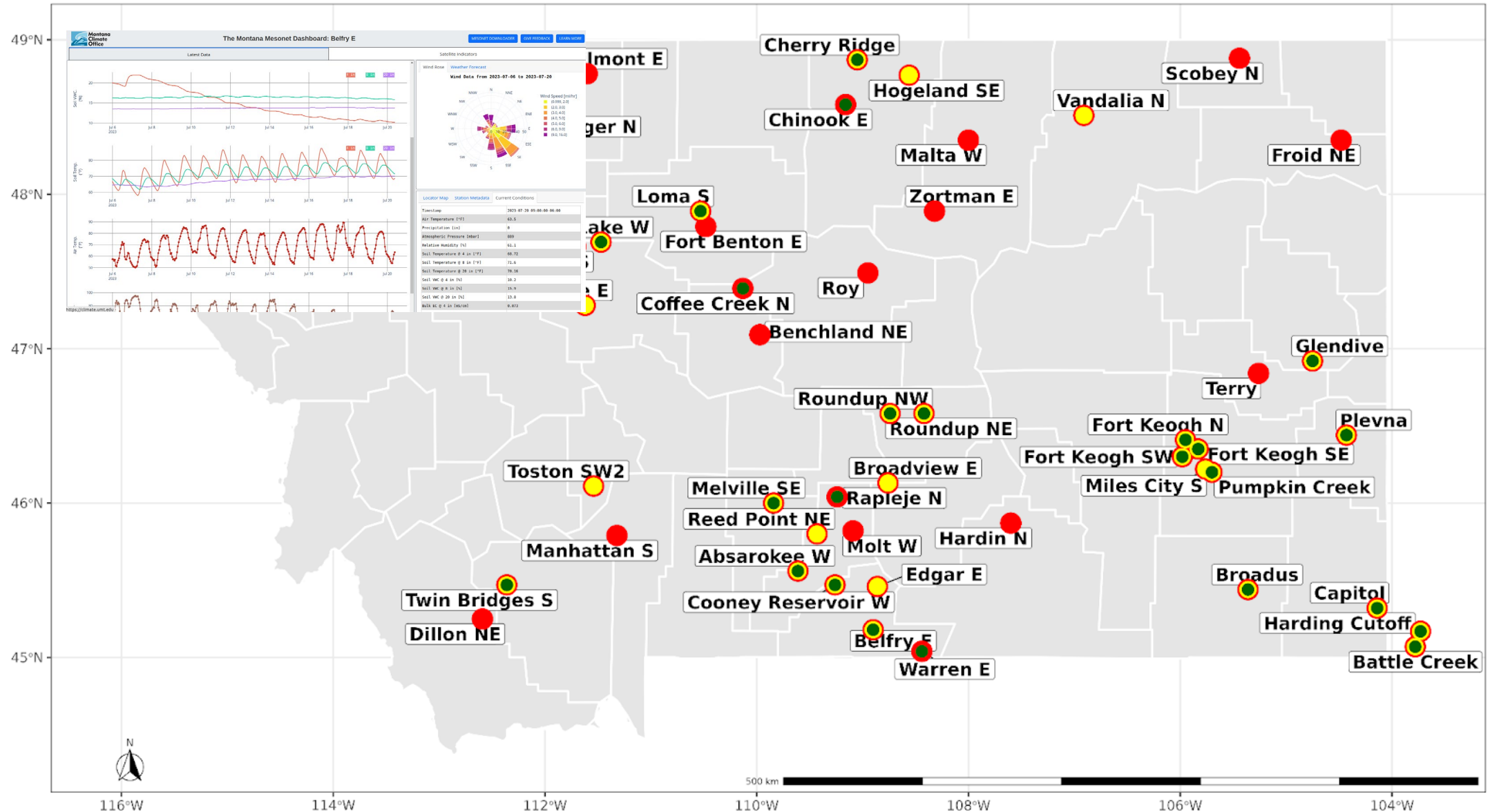
1) Which environmental drivers are most determinant for seasonal vegetation dynamics in semi-arid ecosystems?

- Is Ψ_{soil} a better predictor of vegetation dynamics than VWC?
- Are atmospheric or subsurface conditions more important for driving vegetation dynamics?

2) Are these drivers consistent when considering seasonal responses vs deviations from normal responses?



Methods – field, laboratory and satellite retrievals



● Sites used in anomaly analysis ● Sites used in laboratory analysis ● Sites used in seasonal analysis

Methods – field, laboratory and satellite retrievals

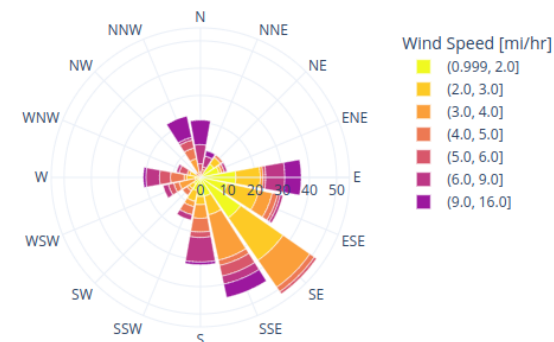


Latest Data

Satellite Indicators

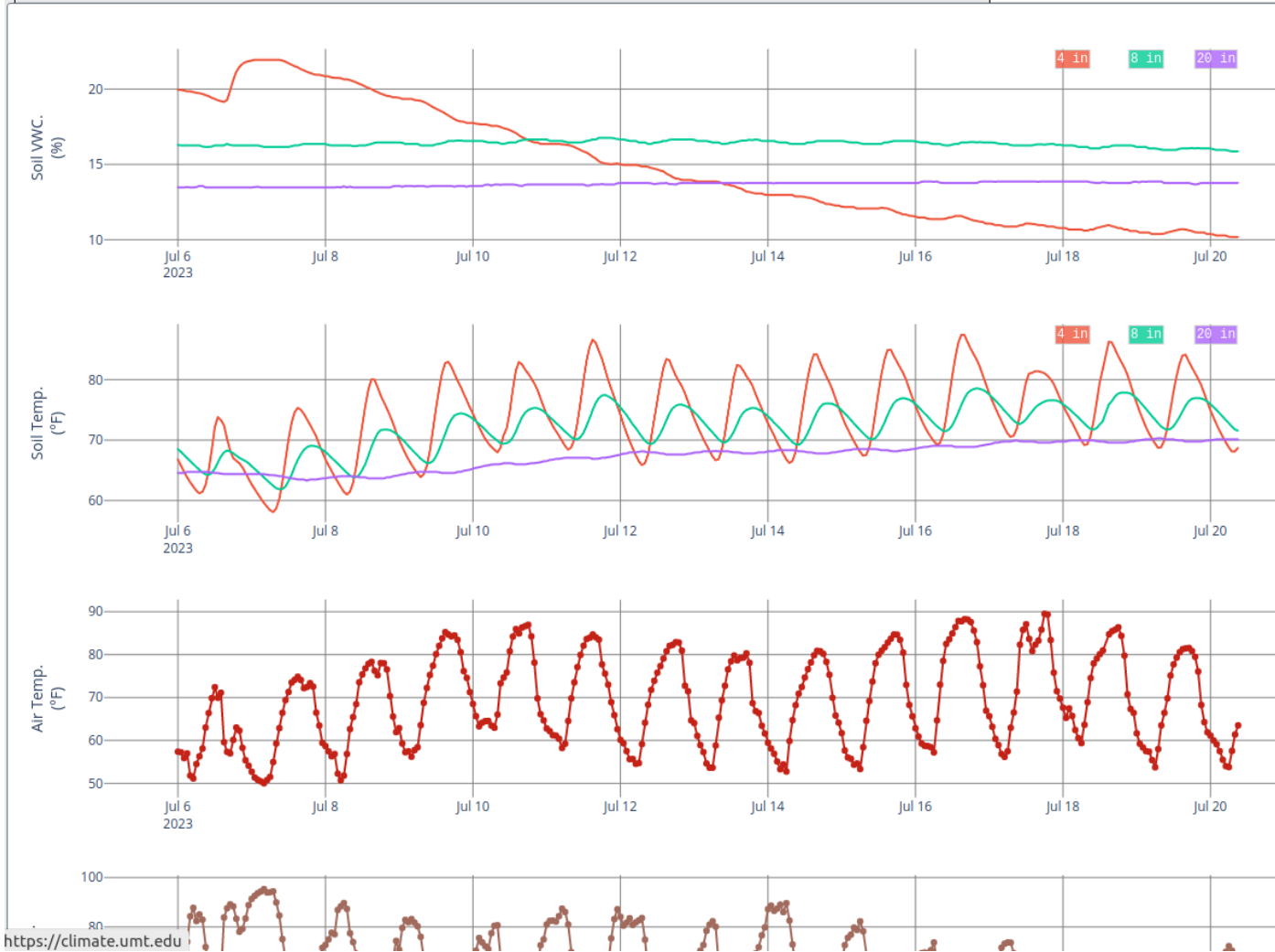
Wind Rose Weather Forecast

Wind Data from 2023-07-06 to 2023-07-20

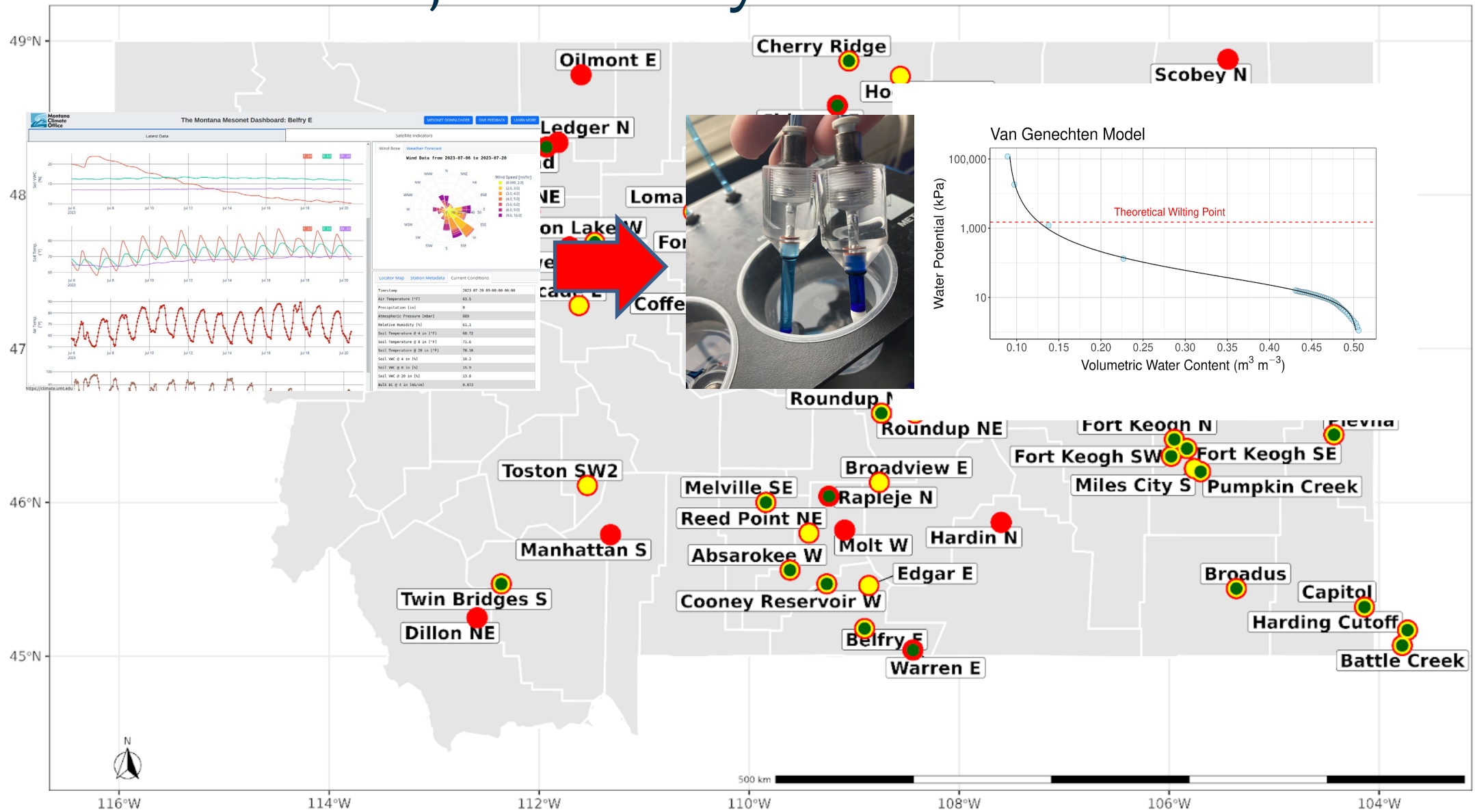


Locator Map Station Metadata Current Conditions

Timestamp	2023-07-20 09:00:00-06:00
Air Temperature [°F]	63.5
Precipitation [in]	0
Atmospheric Pressure [mbar]	889
Relative Humidity [%]	61.1
Soil Temperature @ 4 in [°F]	68.72
Soil Temperature @ 8 in [°F]	71.6
Soil Temperature @ 20 in [°F]	70.16
Soil Wc @ 4 in [%]	10.2
Soil Wc @ 8 in [%]	15.9
Soil Wc @ 20 in [%]	13.8
Bulk EC @ 4 in [mS/cm]	0.073

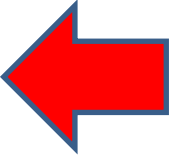
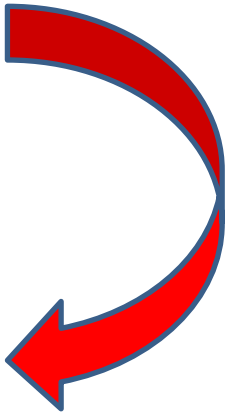
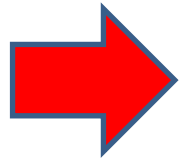
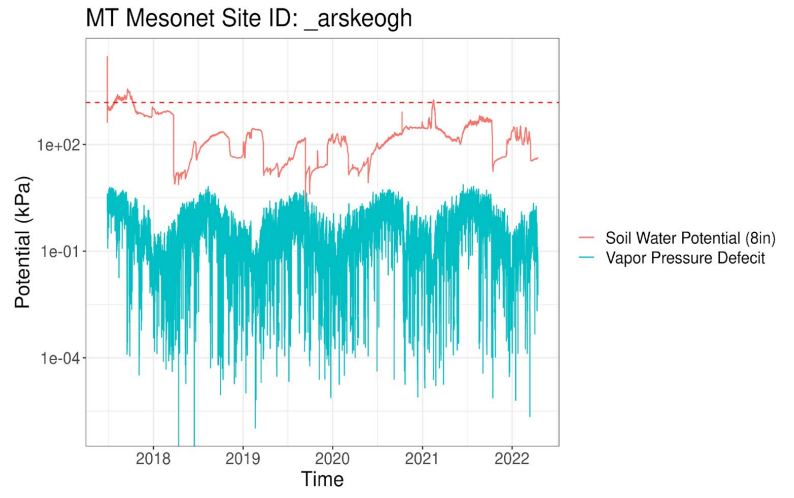
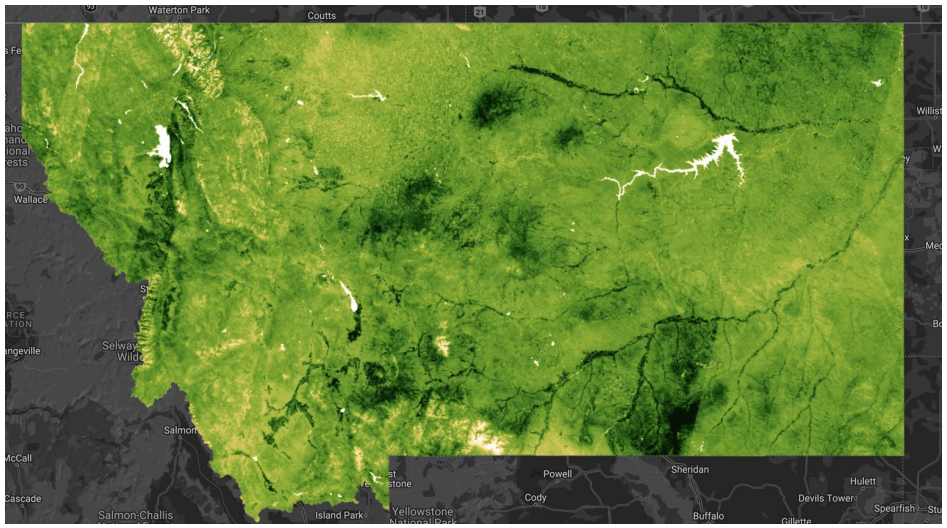
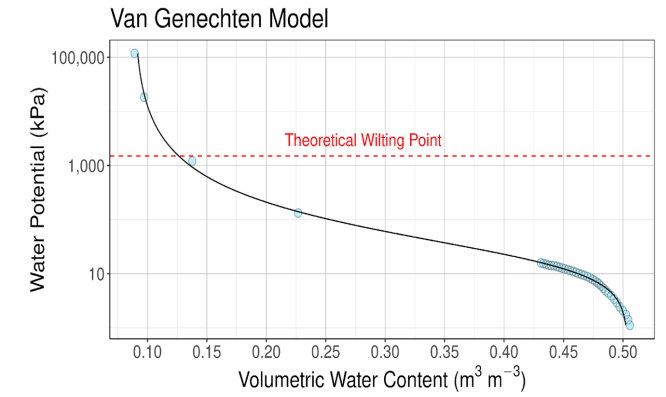
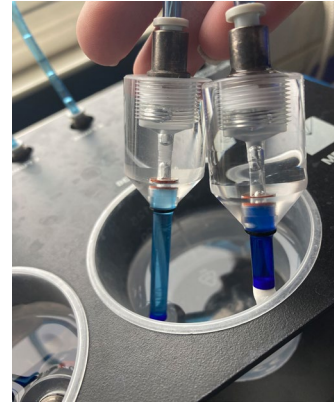
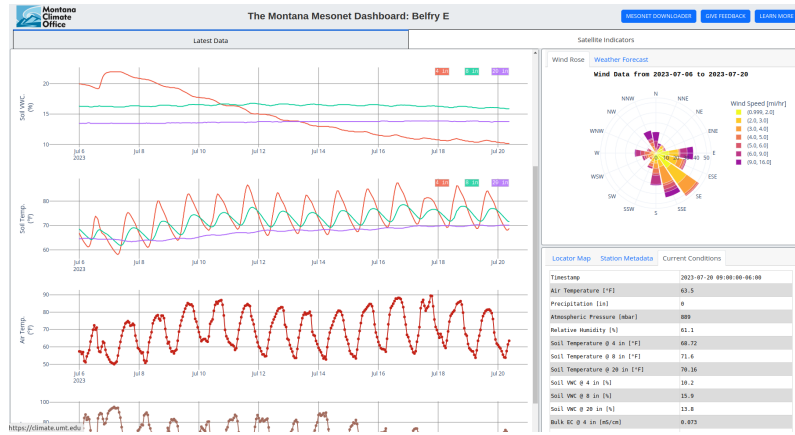


Methods – field, laboratory and satellite retrievals



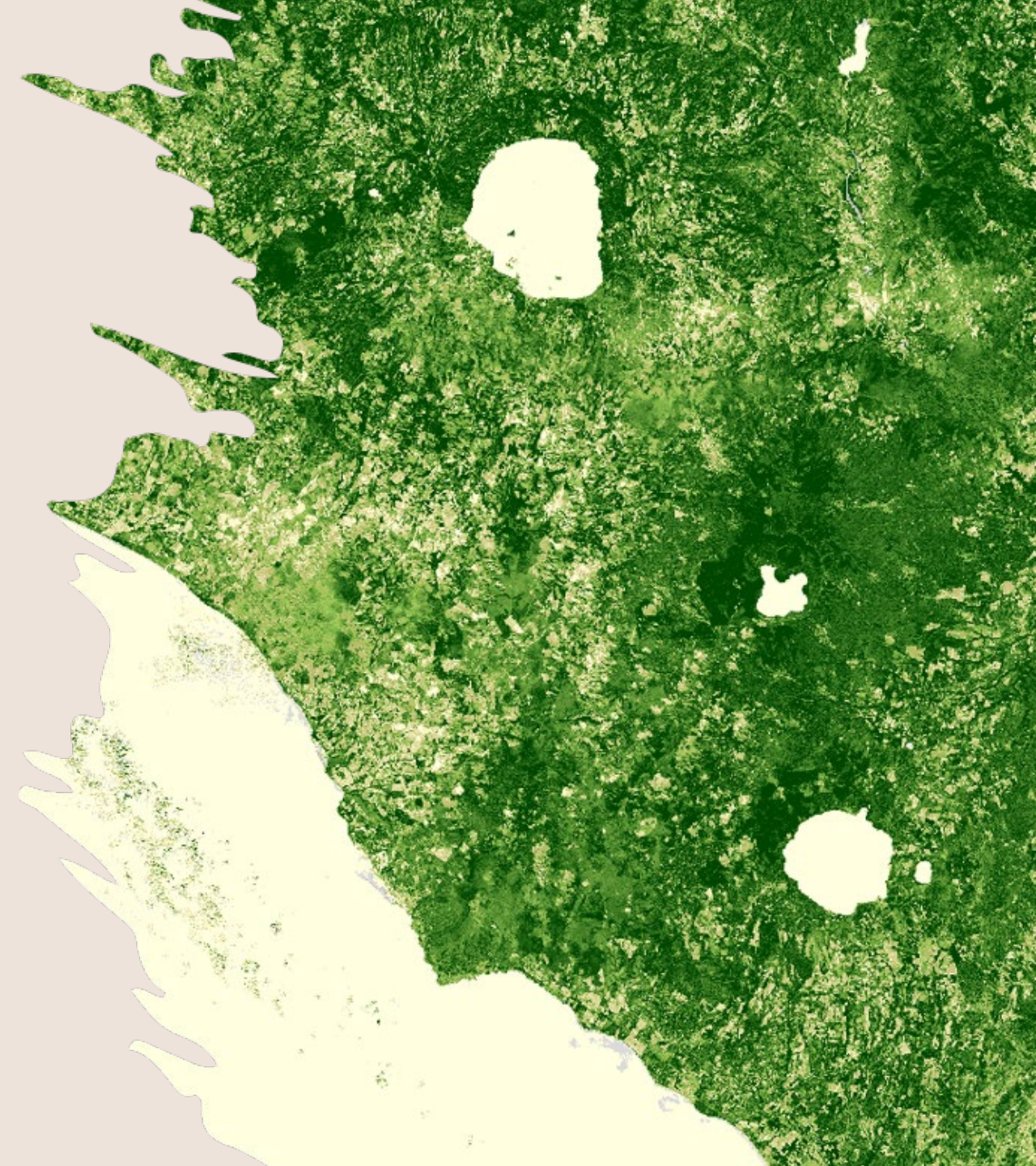
● Sites used in anomaly analysis ● Sites used in laboratory analysis ● Sites used in seasonal analysis

Methods – field, laboratory and satellite retrievals



1) Seasonal analysis

2) Anomaly analysis



1) Seasonal analysis

- NIRv: near-infrared reflectance

$$NIR_v = (NDVI - 0.08) \times NIR$$

- EVI: Enhanced Vegetation Index

$$EVI = G \times \frac{(NIR - Red)}{(NIR + C_1 \times Red - C_2 \times Blue + L)}$$





- SIF: Solar Induced Fluorescence

$$SIF = PAR * FPAR * \Phi_F * f_{esc}$$

- NIRv is the best indicator for semi-arid regions



Satellite solar-induced chlorophyll fluorescence and near-infrared reflectance capture complementary aspects of dryland vegetation productivity dynamics

Xian Wang^a  , Joel A. Biederman^b, John F. Knowles^{b c}, Russell L. Scott^b, Alexander J. Turner^d, Matthew P. Dannenberg^e, Philipp Köhler^f, Christian Frankenberg^f, Marcy E. Litvak^g, Gerald N. Flerchinger^h, Beverly E. Lawⁱ, Hyojung Kwonⁱ, Sasha C. Reed^j, William J. Parton^k, Greg A. Barron-Gafford^c, William K. Smith^a  



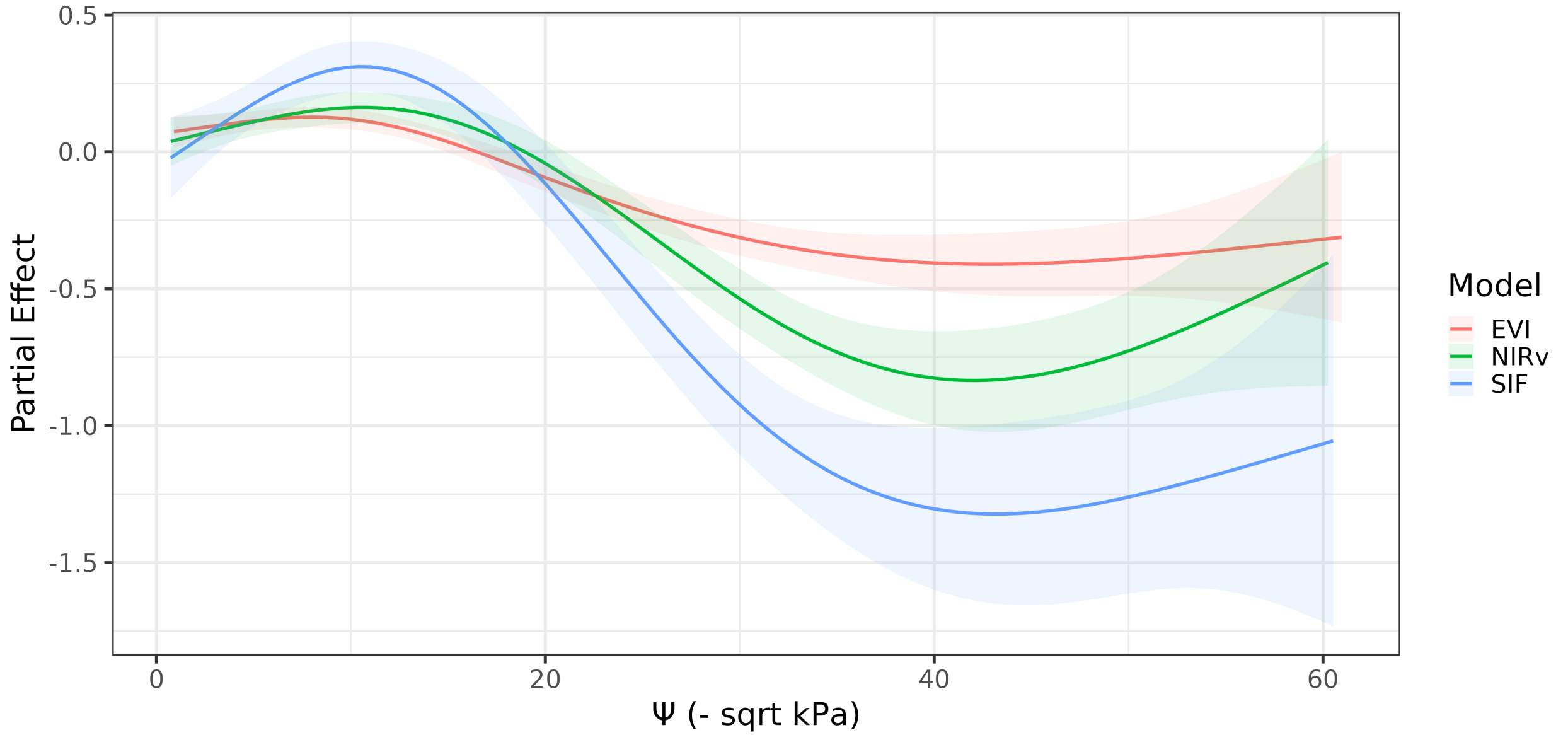
Model	Variables	Partial Deviance Change	edf	Ref.df	F	p-value	Deviance Explained
NIRv	Ψ (sqrt kPa)	75.46617	4.157935	4.686126	34.569215	0.0000000	21%
NIRv	VPD (kPa)	67.95840	3.946075	4.567544	19.981929	0.0000000	21%
NIRv	VWC (m ³ /m ³)	46.21306	4.937319	4.997401	8.475839	0.0000000	21%
NIRv	Soil Temperature (C)	41.54631	3.382117	4.071247	3.117895	0.0132497	21%

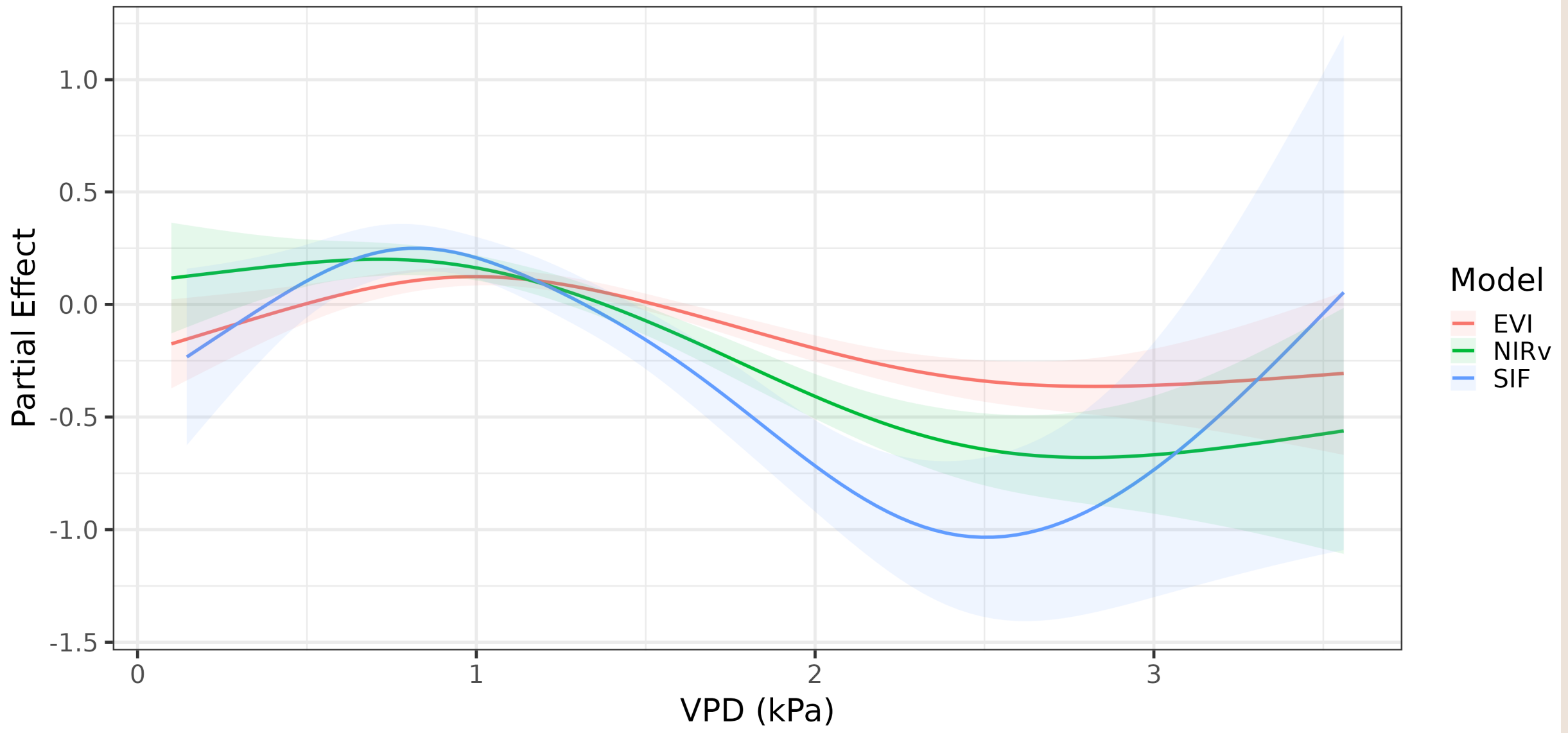
EVI	Ψ (sqrt kPa)	23.31468	4.053197	4.614957	30.568851	0.0000000	25.61%
EVI	VPD (kPa)	13.70161	4.016904	4.624503	18.851562	0.0000000	25.61%
EVI	VWC (m ³ /m ³)	10.51711	4.954890	4.998600	8.320648	0.0000000	25.61%
EVI	Soil Temperature (C)	7.06880	4.792094	4.977813	8.188450	0.0000002	25.61%

SIF	Ψ (sqrt kPa)	142.68240	3.959257	4.528900	37.271270	0.0000000	25.40%
SIF	VPD (kPa)	87.90700	4.451795	4.871227	13.071183	0.0000000	25.40%
SIF	Soil Temperature (C)	83.89199	4.058962	4.634963	12.347370	0.0000000	25.40%
SIF	VWC (m ³ /m ³)	62.13610	4.816524	4.981740	7.280263	0.0000024	25.40%

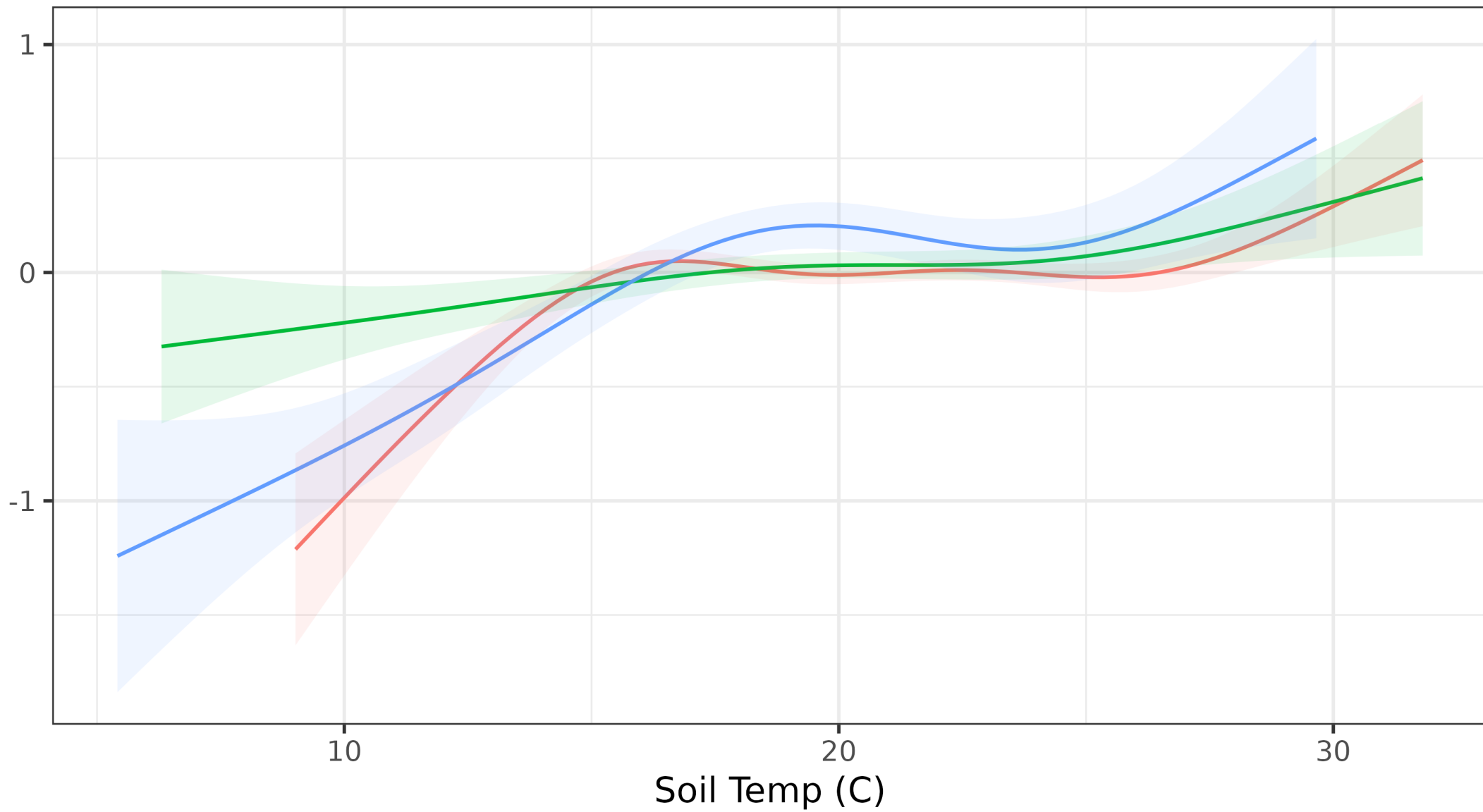
Full GAM Model Summary Outputs

- Ψ (kPa) was the best predictor for each model
- The remaining predictors varied in importance, depending on the model



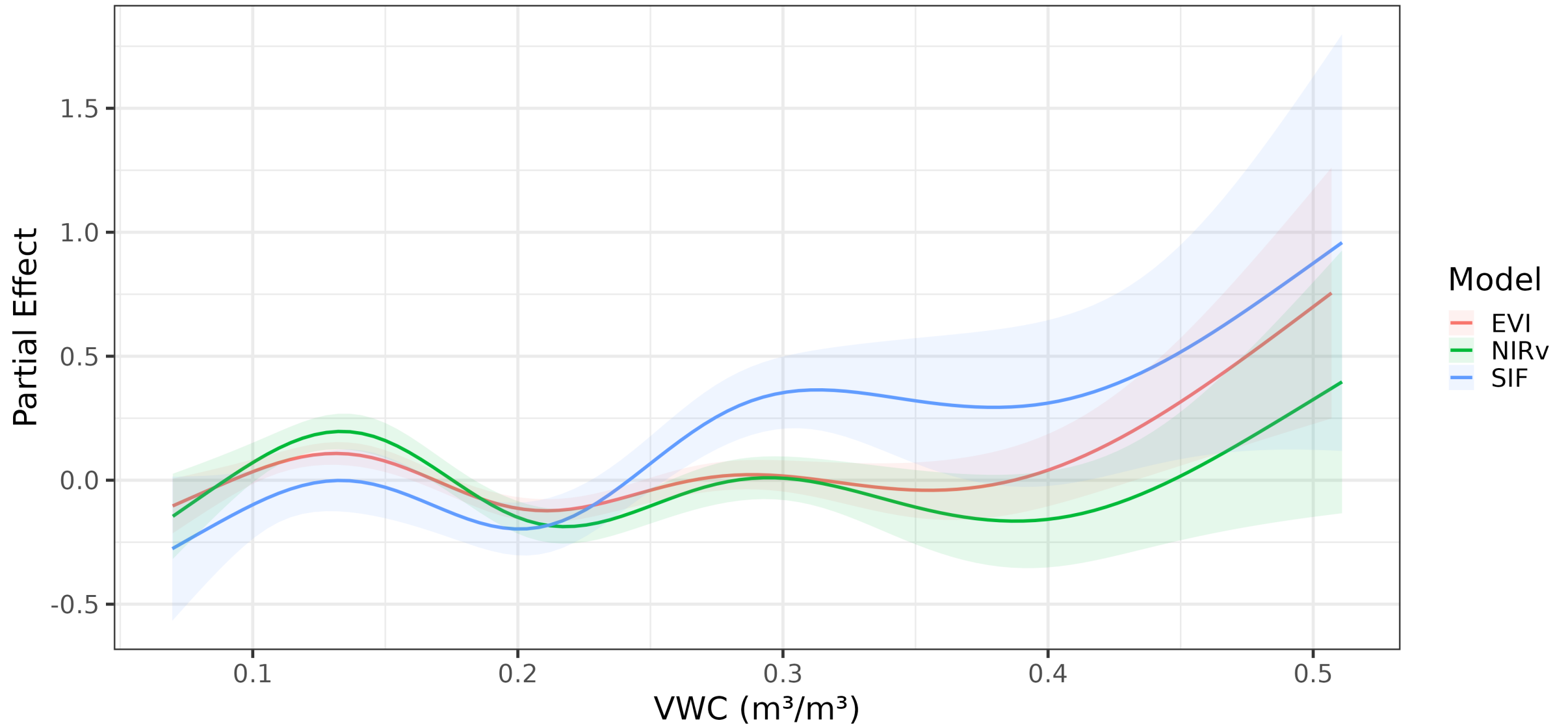


Partial Effect

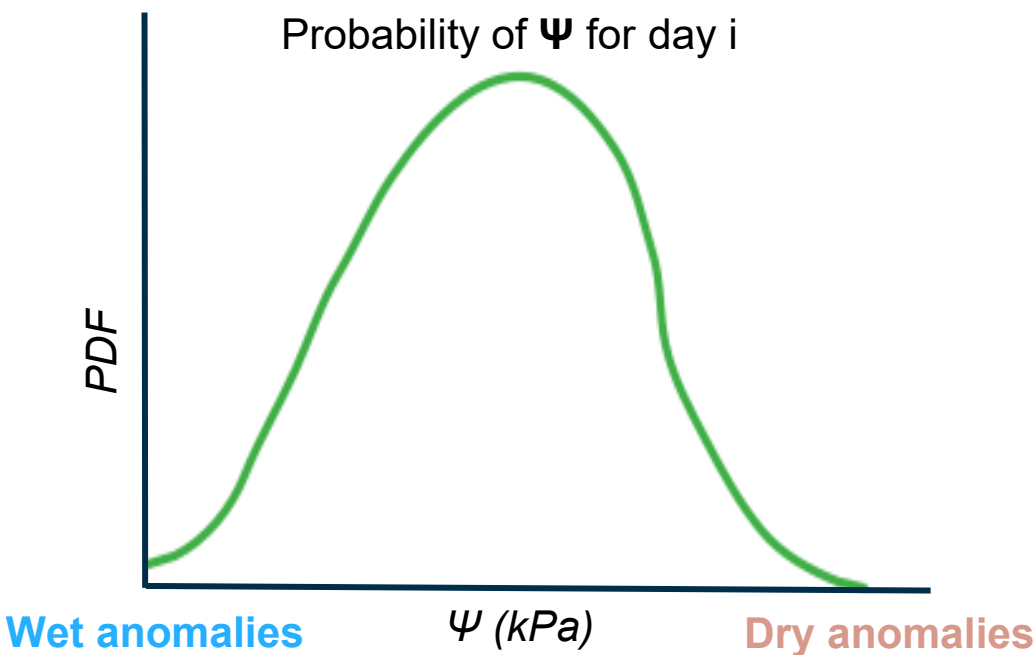
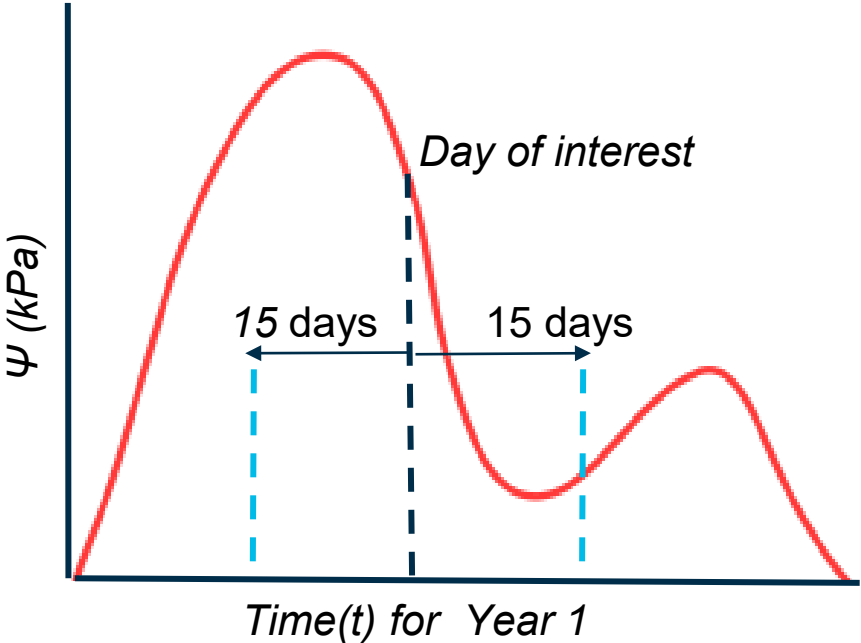


Model

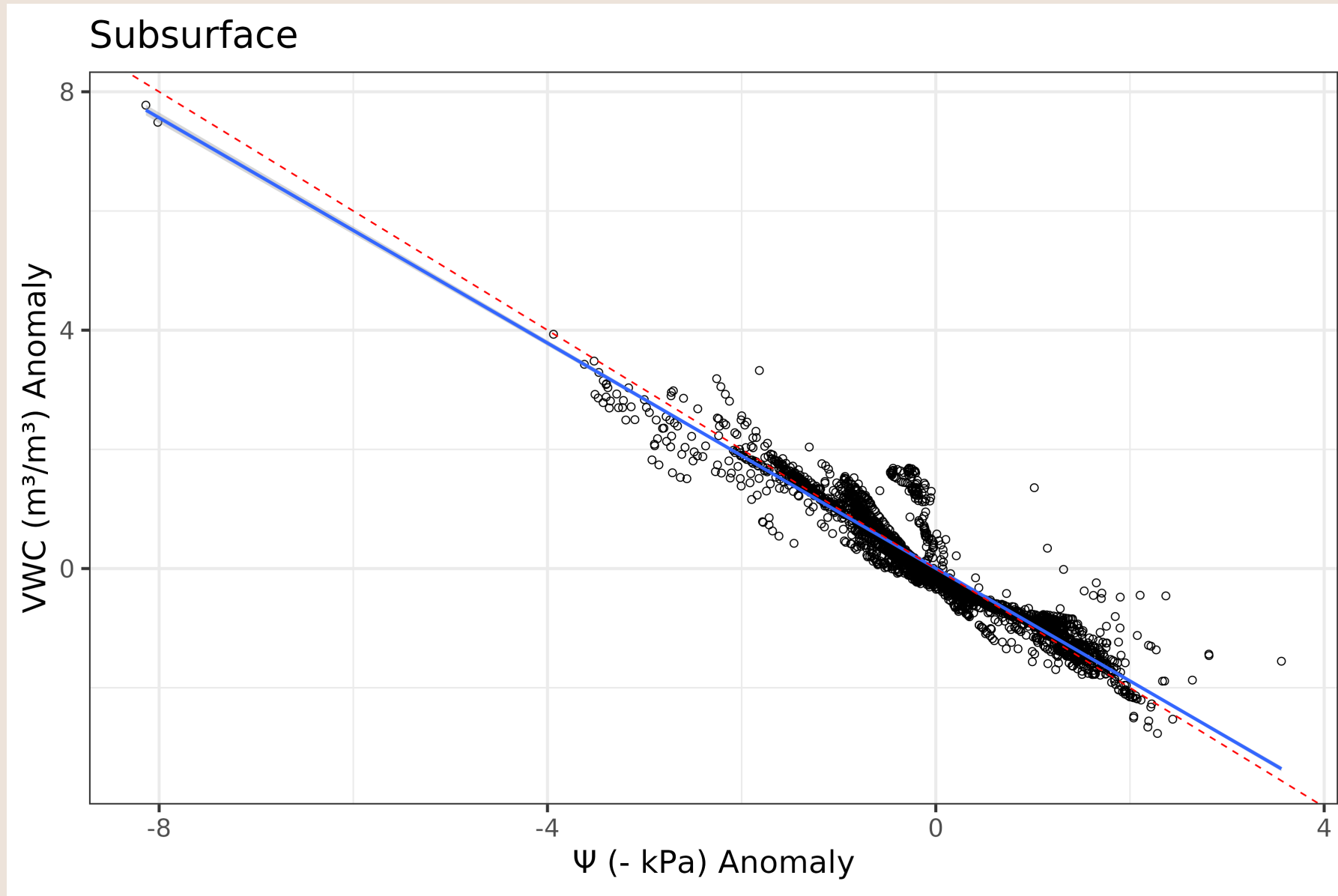
- EVI
- NIRv
- SIF



Anomalies were computed using a 31 Day Moving Window Analysis

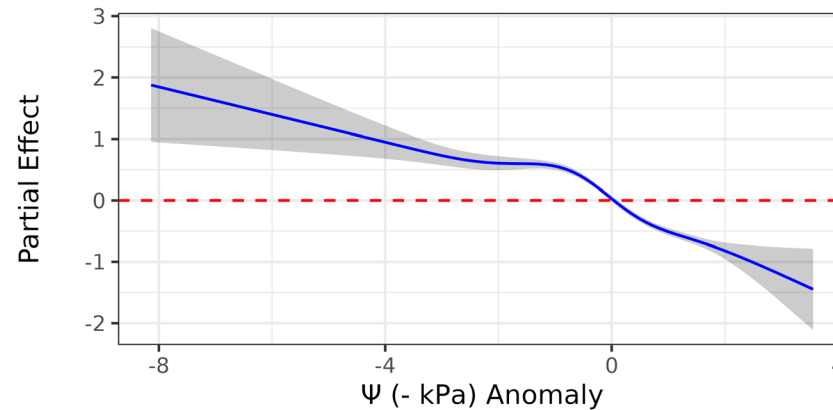


3) Anomaly Analysis



Ψ (kPa) and VWC are highly correlated

Parametric Anomaly NIRv



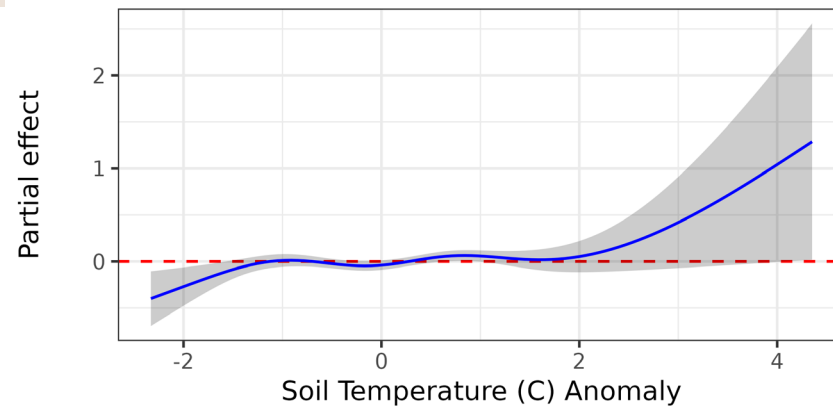
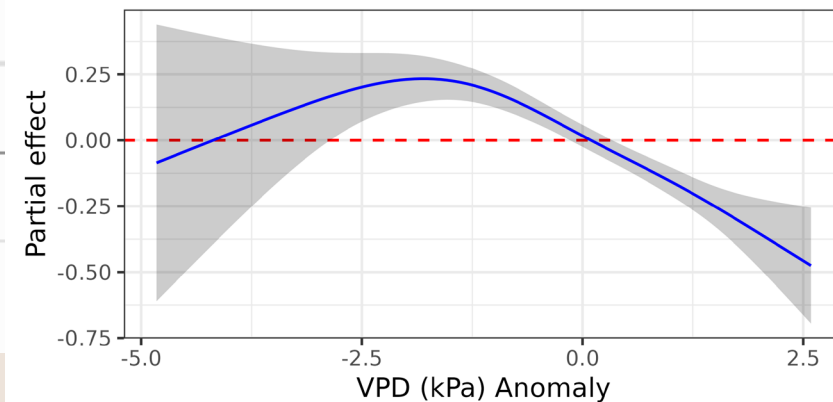
NIRv standardized anomaly GAM model, Deviance E

Variables

Ψ (kPa) Anomaly

VPD (kPa) Anomaly

Soil Temperature (C) Anomaly

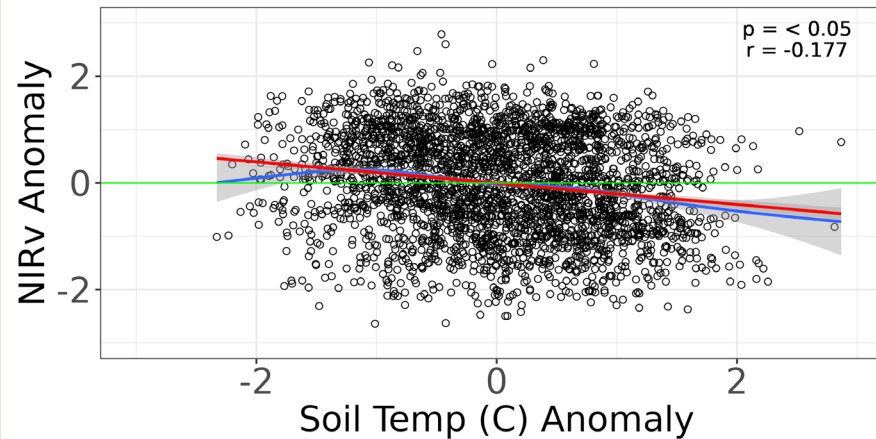
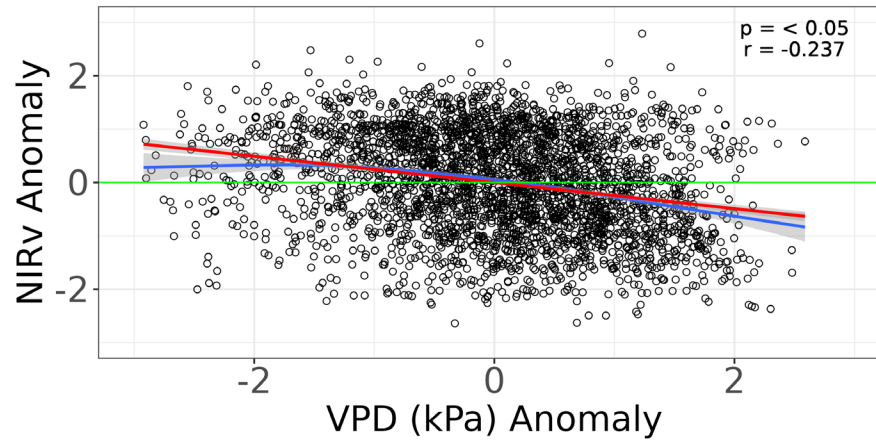
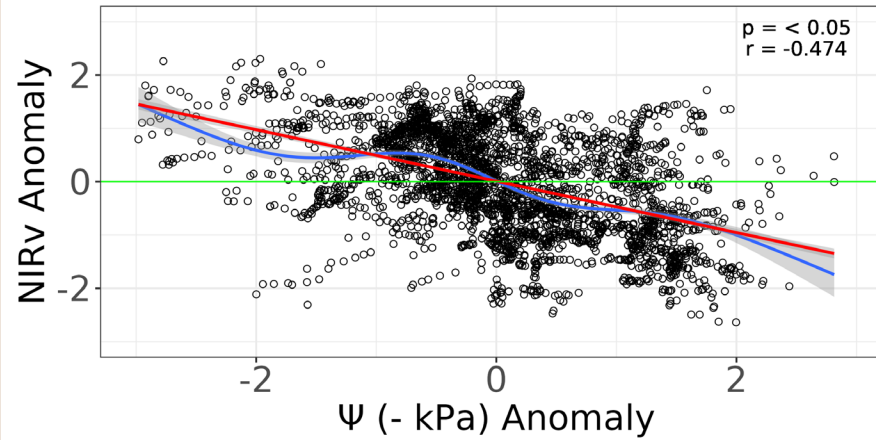


	Ref.df	F	p-value
Ψ (kPa) Anomaly	4.967091	167.677514	0.0000000
VPD (kPa) Anomaly	3.958550	18.310603	0.0000000
Soil Temperature (C) Anomaly	4.958894	2.890325	0.0170005

Partial effects of predictor anomaly

- Wetter values of Ψ (kPa) explain **greener** anomalies for vegetation.
- Drier values of Ψ (kPa) explain **browner** anomalies for vegetation

Anomaly Analysis



Anomaly Analysis take-away point:

- Subsurface conditions explain vegetation anomalies
- When data is standardized for anomaly analysis, VWC and Ψ (kPa) have a nearly linear 1:1 relationship

- Ψ (kPa) is an important predictor variable for seasonal semi-arid vegetation dynamics, but is not needed for standardized anomaly analysis
- Subsurface conditions are a better predictor for semi-arid vegetation anomalies than atmospheric conditions

Atmosphere



Soil



- VPD emerged as a secondary driver of vegetation productivity in the absence of Ψ (kPa) limitations

Atmosphere



Soil



Thank you to my advisors,
Kelsey Jensco and Zach
Hoyleman, for their support and
mentorship



5 year cooperative agreement
with MCO (L16AC00359)

Questions?