Supplemental Materials for *Soil moisture interacts with temperature to affect plant phenology*

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Supplemental Methods

Equation for phenology models: Response variable (y) is day of year of the phenological event (budburst, leafout, or flowering). Predictors are measured air temperature (T) and soil moisture(SM). Random effects are species (sp, random slopes and intercepts), and site and year nested within site (random intercepts).

$$y_i = \alpha_{sp[i],site[year[i]]} + \beta_{temp_{sp[i]}} + \beta_{mois_{sp[i]}} + \beta_{temp:mois_{sp[i]}} + \epsilon_i \tag{1}$$

$$\alpha_{sp} \sim N(\mu_{sp}, \sigma_{sp}) \tag{2}$$

$$\mu_{site[year]} \sim N(\mu_{siteyr}, \sigma_{siteyr}) \tag{3}$$

$$\mu_{site} \sim N(\mu_{site}, \sigma_{site}) \tag{4}$$

$$\beta_{temp_{sp}} \sim N(\mu_{\beta_{temp}}, \sigma_{\beta_{temp}}) \tag{5}$$

$$\beta_{mois_{sp}} \sim N(\mu_{\beta_{mois}}, \sigma_{\beta_{mois}}) \tag{6}$$

$$\beta_{temp:mois_{sp}} \sim N(\mu_{\beta_{temp:mois}}, \sigma_{\beta_{temp:mois}}) \tag{7}$$

References to include

- Later flowering is associated with low precipitation, at least in part (Crimmins et al 2010)
- Ganjurjav et al 2020
- Cabon 2020

Supplemental Tables

Table 1: **Experimental sites and phenophases included in the ExPhen database**. Experimental sites correspond to the map (Figure S1). We give the study ID, location, source, years of data included, ecosystem, number of species, and phenophases included: budburst (bb), leafout (lo), flowering (fl), fruiting (fr), or senesence (sen) day of year. Note that some sites may have multiple sources; however, we list only one here.

study	location	source	data years	ecosystem	species	phenophases
exp01	Waltham, MA, USA	Hoeppner and Dukes 2012	2009-2011	grassland	44	bb,lo,fl
exp02	Montpelier, France	Morin et al. 2010	2004	temperate deciduous forest	5	fl,fr
exp03	Duke Forest, NC, USA	Clark et al. 2014	2009-2014	temperate deciduous forest	37	bb,lo
exp04	Harvard Forest, MA, USA	Clark et al. 2014	2009-2012	temperate deciduous forest	29	bb,lo
exp07	Harvard Forest, MA, USA	Pelini et al. 2011	2010-2015	temperate deciduous forest	8	bb,lo,sen
exp09	Stone Valley Forest, PA, USA	Rollinson and Kaye 2012	2009-2010	temperate deciduous forest	120	lo,fl,fr,sen
exp10	Duke Forest, NC, USA	Marchin et al. 2015	2010-2013	temperate deciduous forest	11	bb,fl
exp12	Kessler Farm Field Laboratory, OK, USA	Sherry et al. 2007	2003	grassland	12	fl,fr

Table 2: **Summaries of budburst, leafout, and flowering models** with centered predictors.

	Population-Level Effects						Site Effects			Site Year Effects			Species Effects		
	mean	error	25%	75%	5%	95%	mean	error	Ngrp	mean	error	Ngrp	mean	error	Ngrp
BBμ_{α}	97.20	5.10	94.10	100.40	89.00	105.20	7.4	4.9	5	9.3	2.5	13	16.10	2.50	41
BBμ_{temp}	-7.80	2.10	-9.20	-6.40	-11.30	-4.20							11.40	1.70	
BBμ_{mois}	-1.70	0.60	-2.10	-1.30	-2.80	-0.70							2.70	0.60	
BB$\mu_{temp:mois}$	0.50	0.50	0.20	0.80	-0.40	1.30							1.70	0.70	
LOμ_{α}	131.40	11.60	124.60	138.40	112.80	149.70	24.7	10.5	5	12.3	3.9	13	12.10	2.20	147
LOμ_{temp}	-9.70	1.50	-10.80	-8.70	-12.20	-7.20							10.70	1.40	
LOμ_{mois}	-0.90	1.00	-1.60	-0.20	-2.70	0.70							4.50	1.30	
LO$\mu_{temp:mois}$	0.00	0.70	-0.50	0.50	-1.20	1.20							5.10	0.70	
FLμ_{α}	165.80	9.10	160.60	171.10	151.40	179.60	11.8	10.1	5	8.1	4.6	8	48.40	3.40	127
FLμ_{temp}	-7.90	1.30	-8.80	-7.00	-10.10	-5.70							5.90	1.20	
FLμ_{mois}	-1.20	0.90	-1.80	-0.60	-2.70	0.40							4.30	1.10	
FL$\mu_{temp:mois}$	-1.20	0.70	-1.70	-0.70	-2.30	0.00							2.40	1.00	

Supplemental Figures

Questions for co-authors:

1. Life forms vs ecosystems figures: Life forms plots histograms of speces level effects whereas ecosystems plots all posterioes- what's your preference?

2. what do you think of density plots: is it fair to say that variance is greater for tempreature, even though the variances relevative to the mean is about the same?

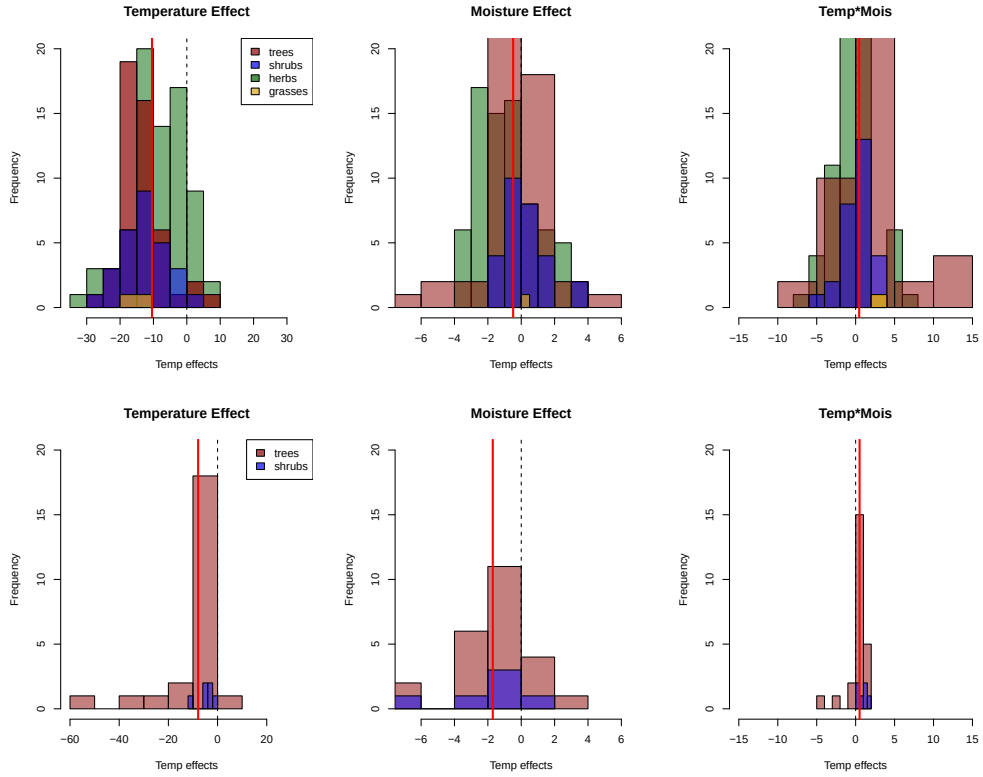

Figure 1: **Effects of temperature, soil moisture, and their interaction do not differ strongly across life forms** for leafout (top) and budburst (bottom) models. Histograms show species-level estimated effects for temeprature, soil, and their inteactions across four life forms (trees, shrubs, forms, and grasses).

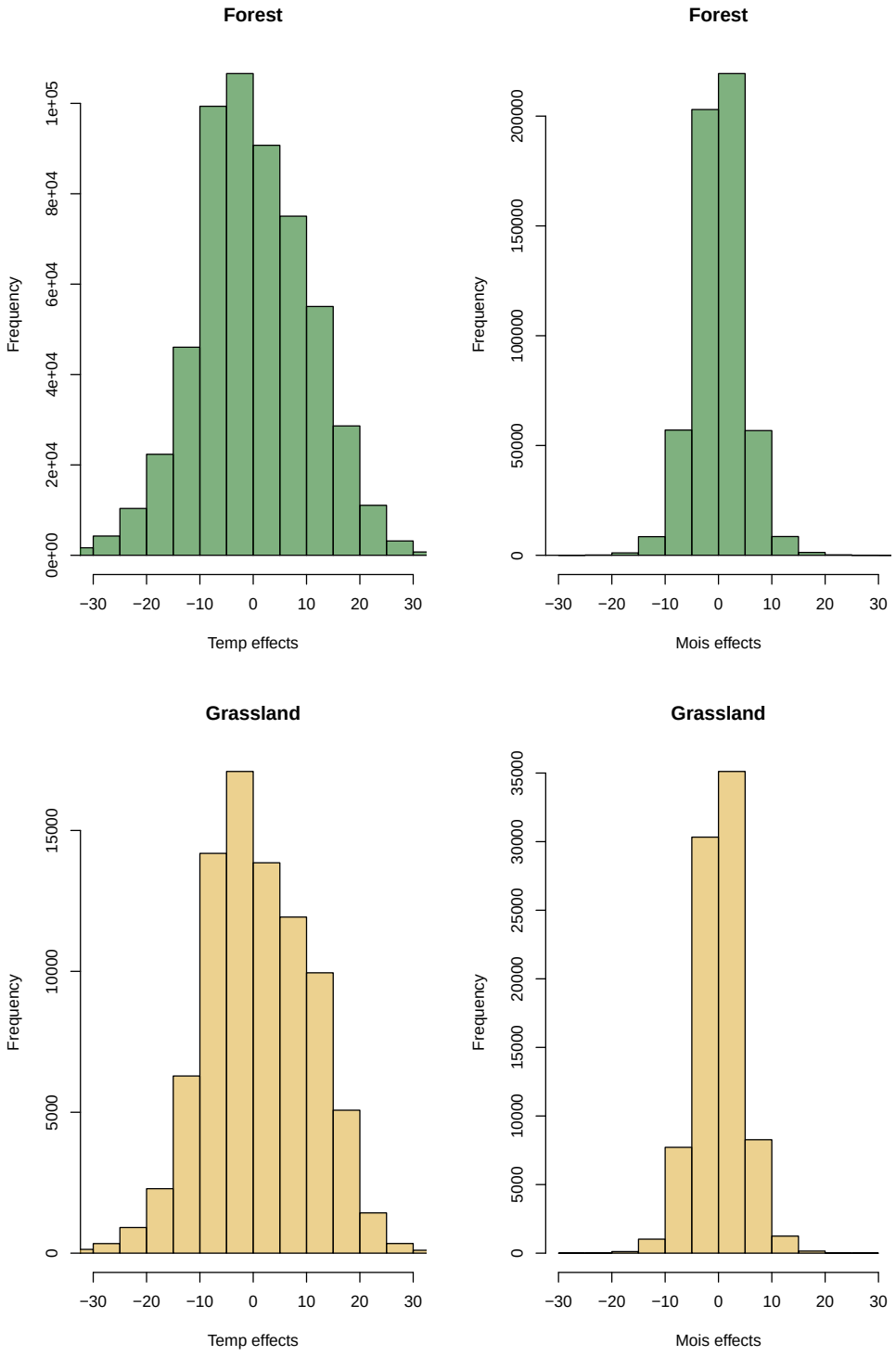

Figure 2: **Effects of temperature and soil moisture do not differ strongly across ecosystems (forest vs grassland) for leafout (top) and budburst (bottom) models.**.