UPDATES TO THE CROP MODEL IN ELM: ROOTS, PLANTING, AND FUTURE DIRECTIONS

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DYNAMIC ROOTS

MOTIVATION AND OBJECTIVES

- Fine roots are responsible for water and nutrient uptake for plant needs
- Roots respond to their environment with foraging strategies to improve nutrient acquisition
- Roots also respond to moisture heterogeneity to enhance water uptake
- Root profiles in models should include time varying structure
- Goal: Develop a new dynamic root approach for the ELM, which accounts for both water and nutrient limitations, such that plants can adjust for whichever resource is limiting

DYNAMIC ROOTS ARE MODIFIED TO ALIGN WITH ROOT MOISTURE STRESS

Add new fine root carbon to each soil layer weighted by water and nitrogen availability (Drewniak, 2019):

$$r_{i,t} = (1 - f) * rw_i + f * rn_i$$

$$f = \sum_{1}^{nlevsoi} max\left(0, \quad w_i * r_{i,t-1}\right)$$

$$w_i = \frac{\Psi_c - \Psi_i}{\Psi_c - \Psi_o} * p_{eff}$$

Water availability in the root zone

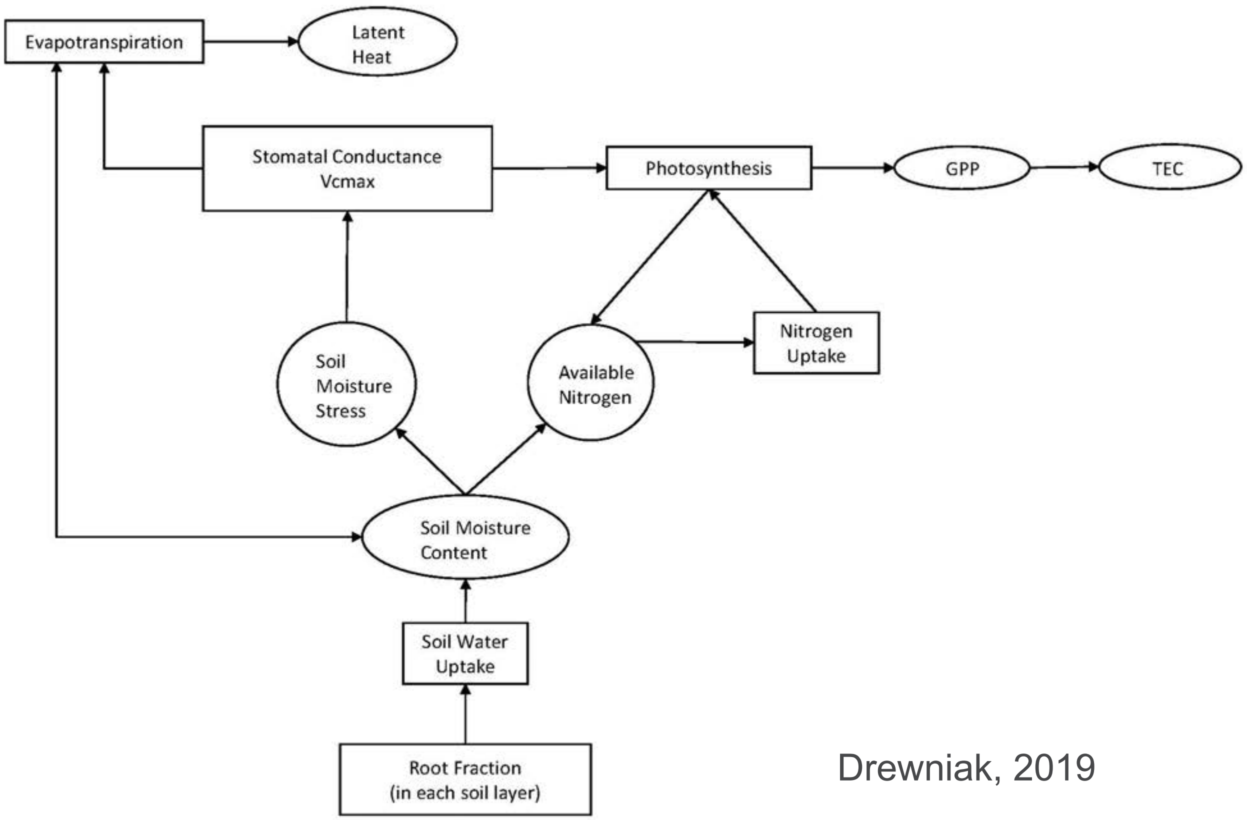
$$rw_i = \frac{R_{w,i}}{\sum_1^{nlevsoi} R_w}$$

Water availability in each soil layer

$$rn_i = \frac{sminn_i * dz_i}{\sum_1^{nlevsoi} sminn_i * dz_i}$$

Nitrogen availability in each soil layer

IMPACTS



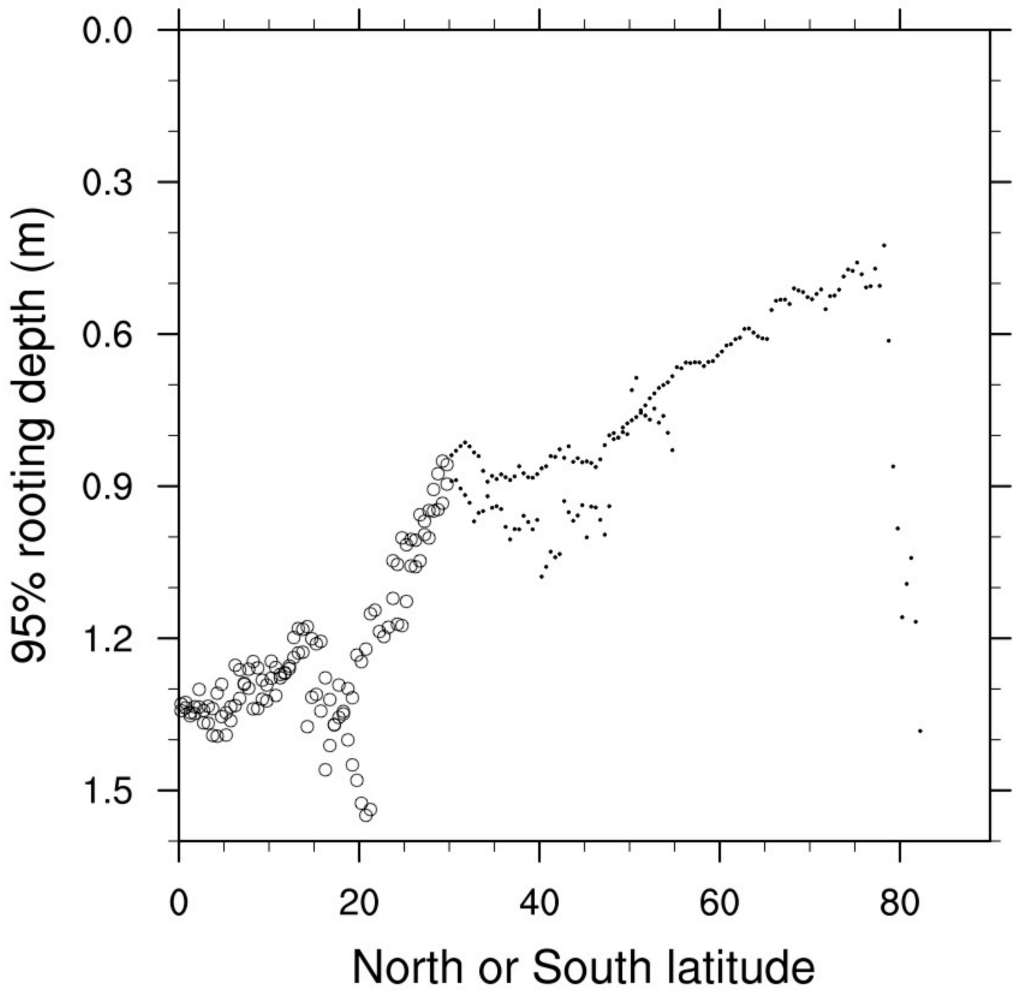
Drewniak, 2019

DYNAMIC ROOTS: SIMULATIONS

Simulation	Dynamic Roots	Water Stress	Nitrogen Stress
CONTROL	NA	NA	NA
DYNROOT	Yes	Dynamic	Yes
DYNROOT-W	Yes	Always stressed, set f = 0 in Eq. 3	No
DYNROOT-50W	Yes	Max. 50%, set f ≤ 0.5 in Eq. 3	Yes
DYNROOT-90W	Yes	Max. 10%, set f ≤ 0.9 in Eq. 3	Yes

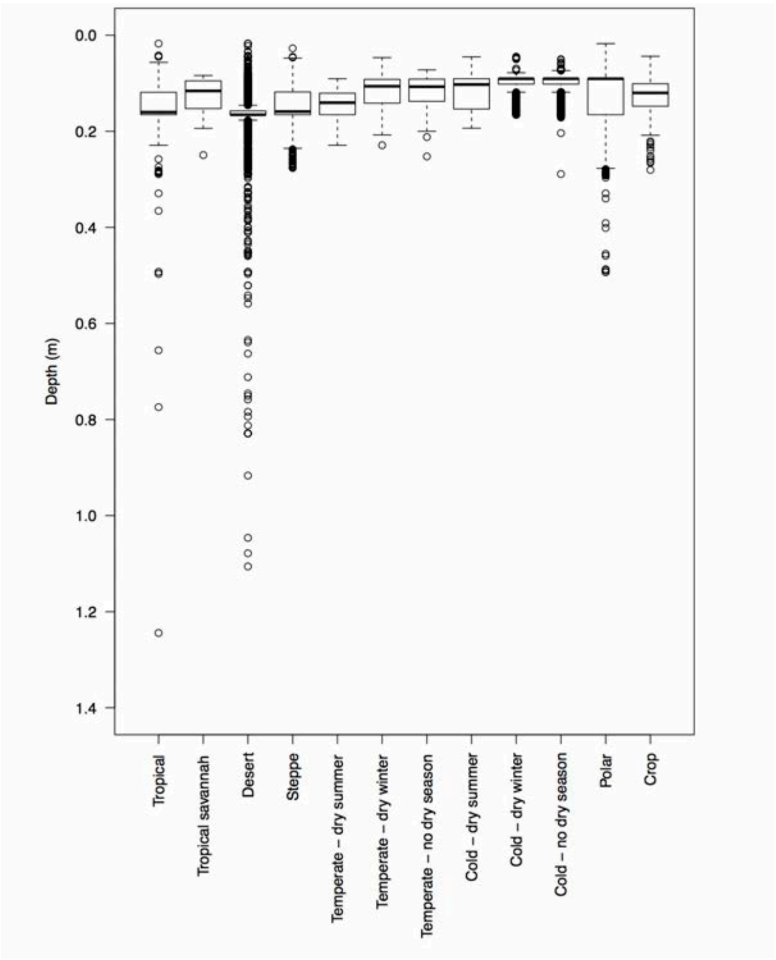
Drewniak, 2019

EFFECTIVE ROOTING DEPTH AS A FUNCTION OF LATITUDE

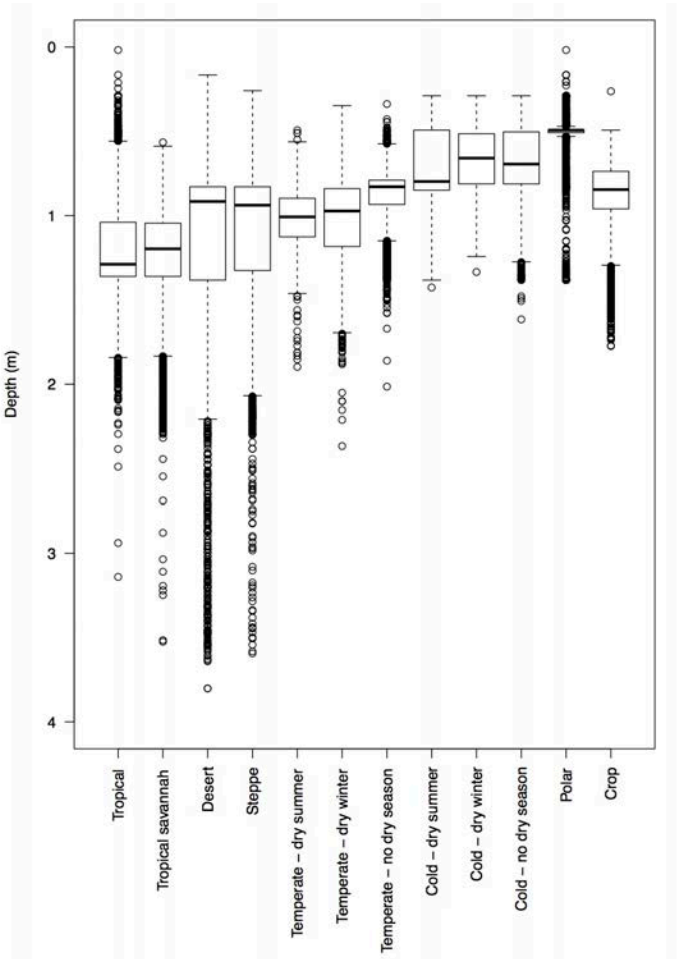


Drewniak, 2019

ROOTING DEPTH ACROSS BIOMES



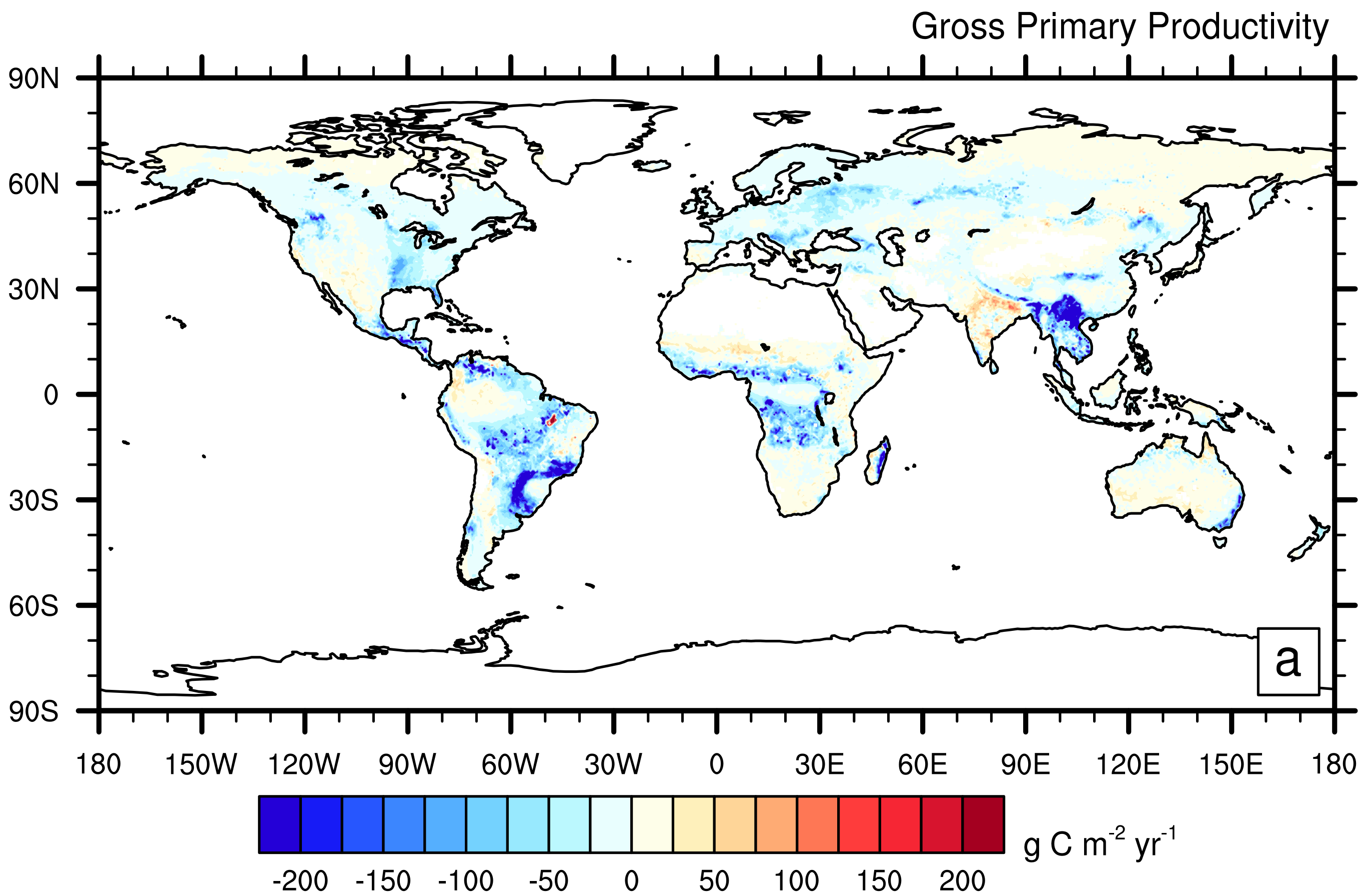
Depth of 50% root biomass



Depth of 95% root biomass

Drewniak, 2019

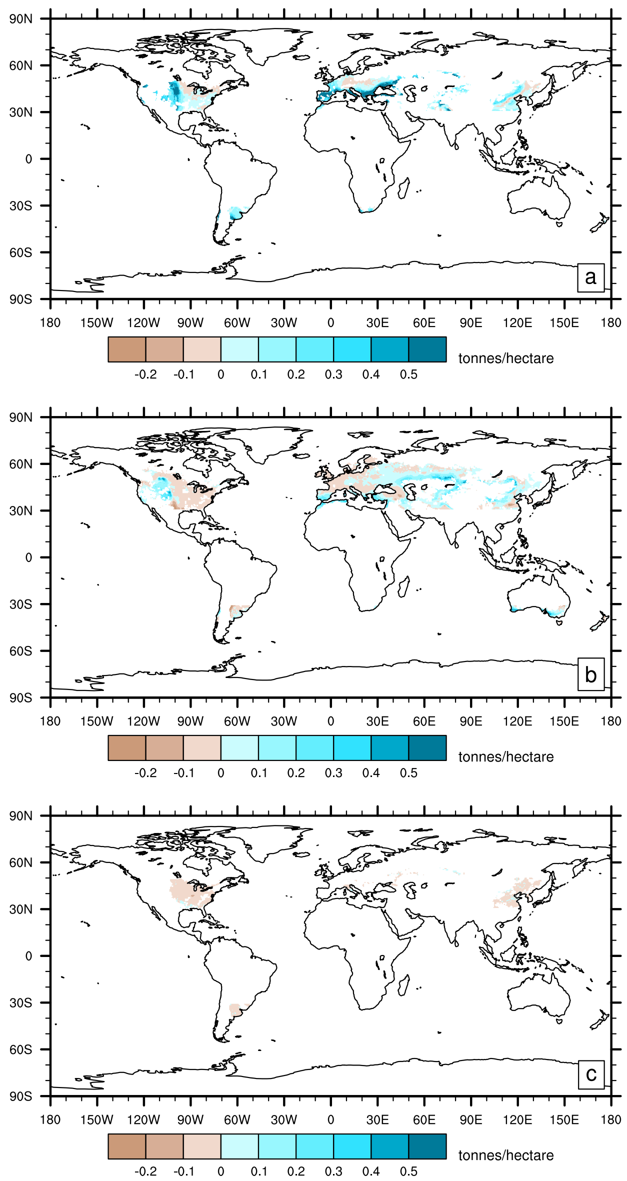
GPP DECREASES IN WET REGIONS; INCREASES IN DRY REGIONS



GPP: DYNROOT – CONTROL

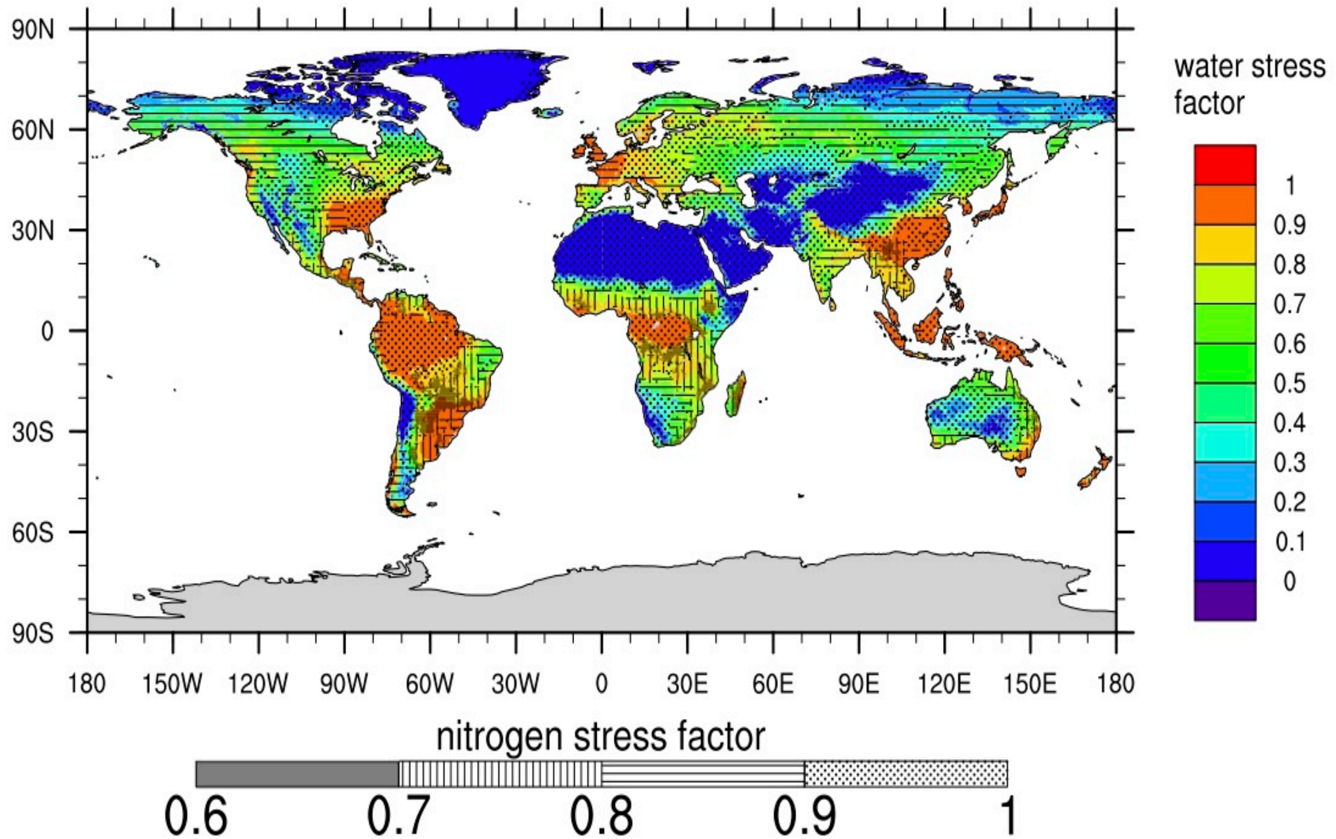
Drewniak, 2019

CHANGES TO CROP YIELD



WATER AND NITROGEN STRESS EXPLAIN THE BULK OF THE MODEL RESPONSE

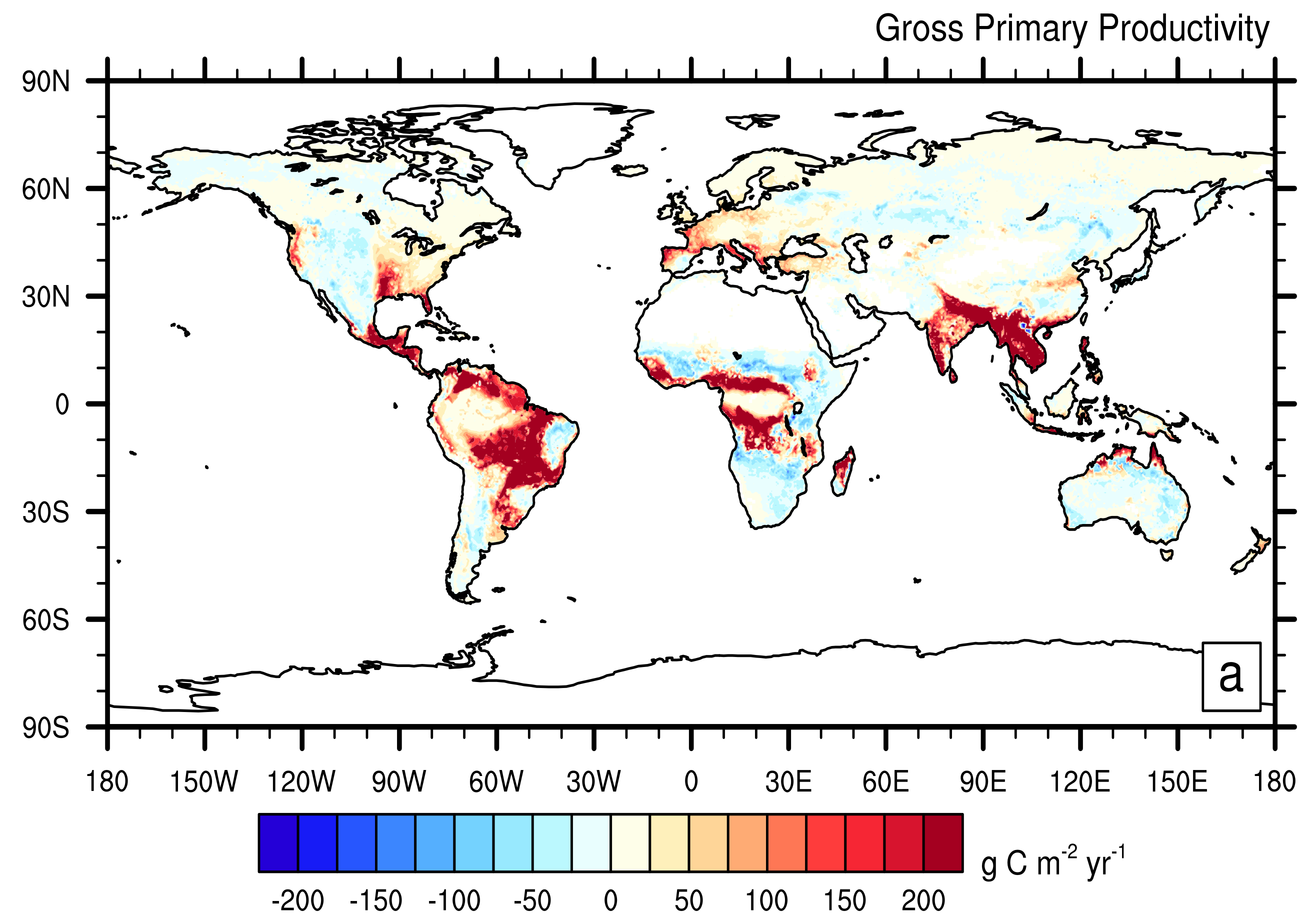
$$r_{i,t} = (1 - f) * rw_i + f * rn_i$$



Overlay of water stress factor (in color) and the nitrogen stress factor (textured) from the DYNROOT simulation.

Drewniak, 2019

UNDER WATER STRESS, GPP INCREASES IN WET REGIONS, DECREASES IN DRY REGIONS



GPP: DYNROOT-W – CONTROL

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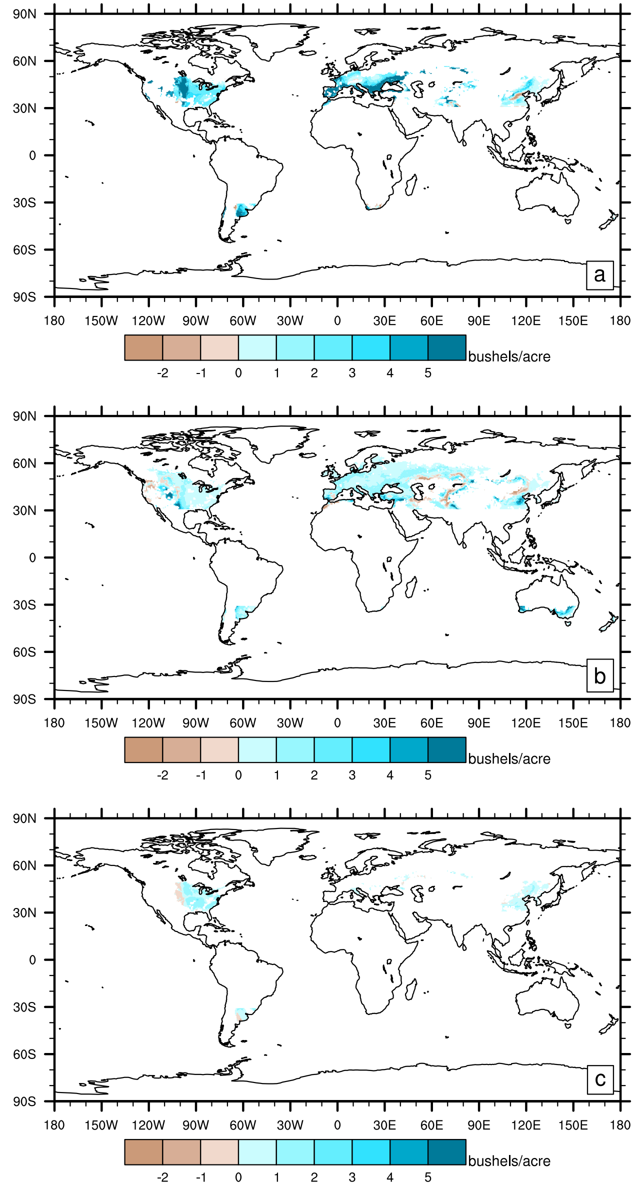
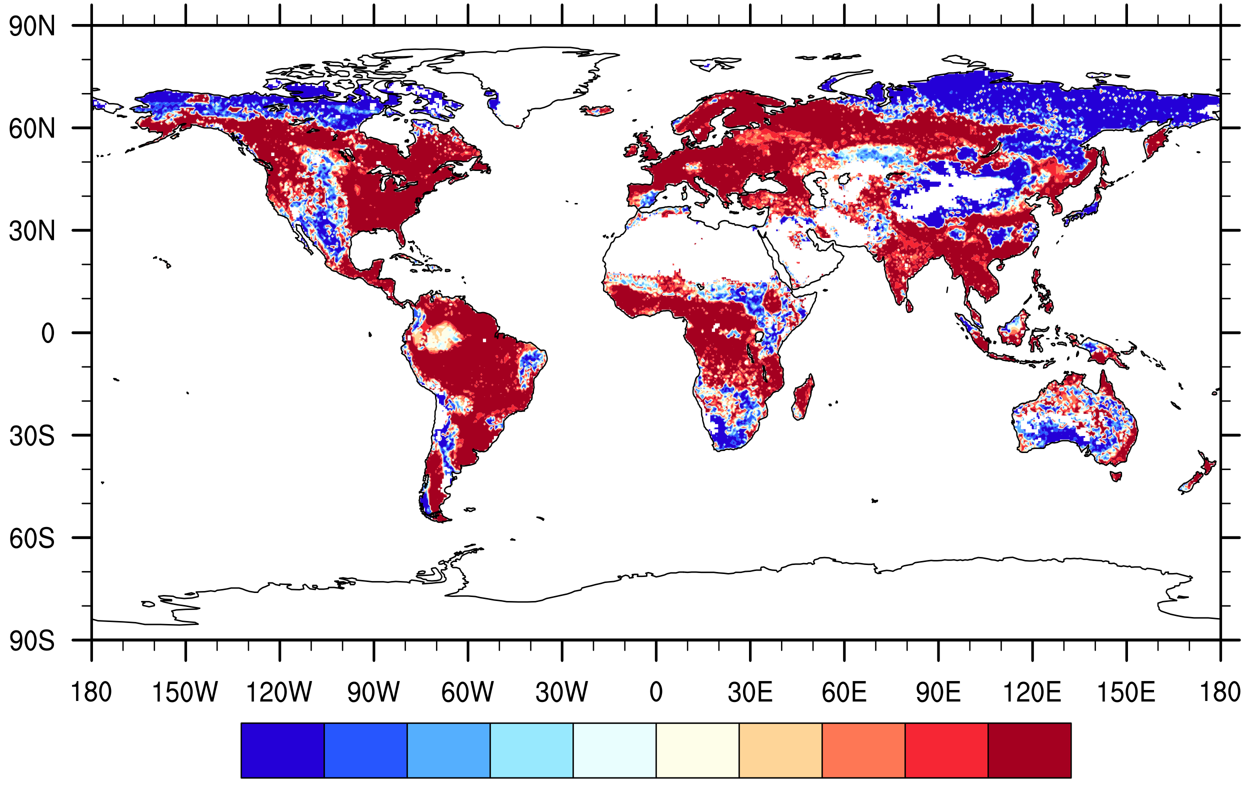
CHANGE IN CROP YIELDS UNDER WATER STRESS



DYNAMIC ROOTS: RESULTS (CONT'D)



Pearson's Correlation Coefficient between GPP and D95 with CONTROL, DYNROOT, DYNROOT-50W, and DYNROOT-90W.

Drewniak, 2019

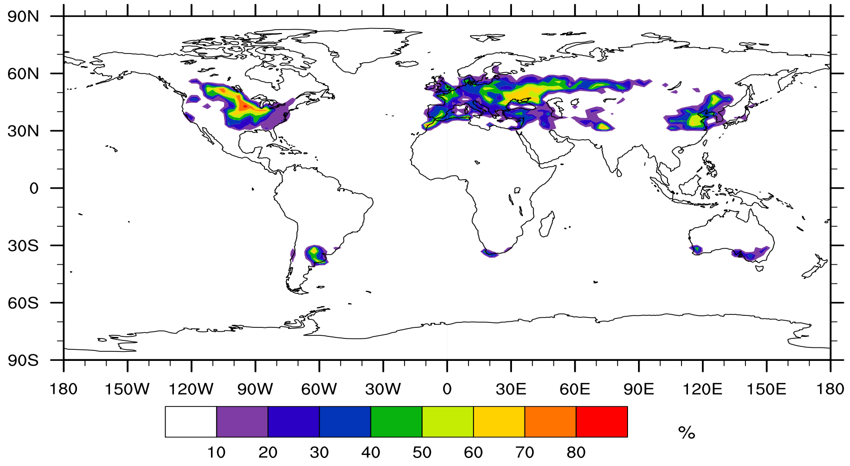
DYNAMIC ROOTS MANUSCRIPT: KEY POINTS

- A new root algorithm, which optimizes for water and nitrogen uptake, is presented for the Energy Exascale Earth System Land Model.
- The new algorithm captures shallow root profiles in dry and tropical ecosystems, but not deep roots in seasonally dry tropical ecosystems.
- The new algorithm marginally improves the model-estimated gross primary productivity compared with satellite observations and suggests that additional processes should be evaluated to increase the effectiveness of dynamic roots.
- The additional model processes include climate dependent root depth, root hydraulics, root form and function, and changing nitrogen uptake to be based on root mass

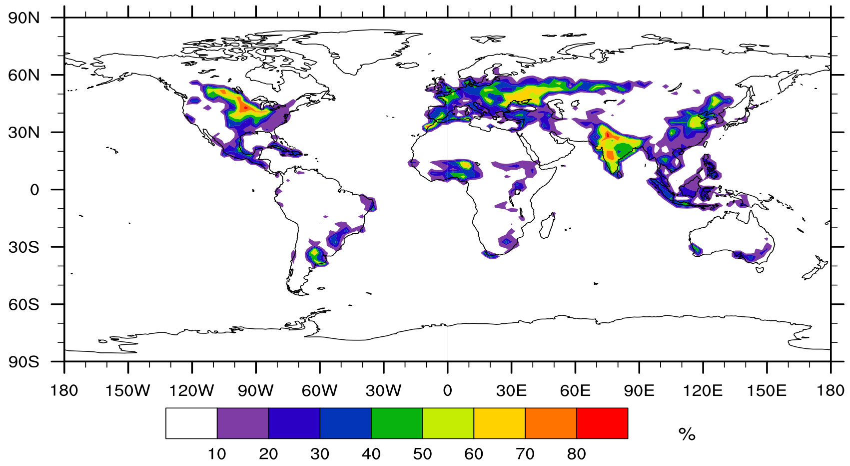
PLANTING DATE

MOTIVATION

Crops are not global in ELM; no crops in the tropics



Where crops are grown in ELM



Global distribution of cropland

Based on Ramankutty et al. 2008

APPROACH: ESTABLISH CLIMATE DRIVEN PLANTING DATES

Establish climate seasonality type → Determine plant month (warm or wet season) → Determine plant day (temperature or precipitation threshold)

Based on (Waha et al., 2012)

SEASONALITY DETERMINED BY TEMPERATURE AND PRECIPITATION COEFFICIENTS OF VARIATION (CV)

$$CV_j = \frac{\sigma_j}{\mu_j}$$

$$\sigma_j = \sqrt{\frac{1}{12-1} \times \sum_{m=1}^{12} \left(\overline{X}_{m,j} - \mu_j\right)^2}$$

$$\mu_j = \frac{1}{12} \times \sum_{m=1}^{12} \overline{X}_{m,j}$$

$$\overline{X}_{m,j} = \alpha \times X_{m.j} + (1-\alpha) \times \overline{X}_{m,j-1}$$

Weighting decrease (0.05)

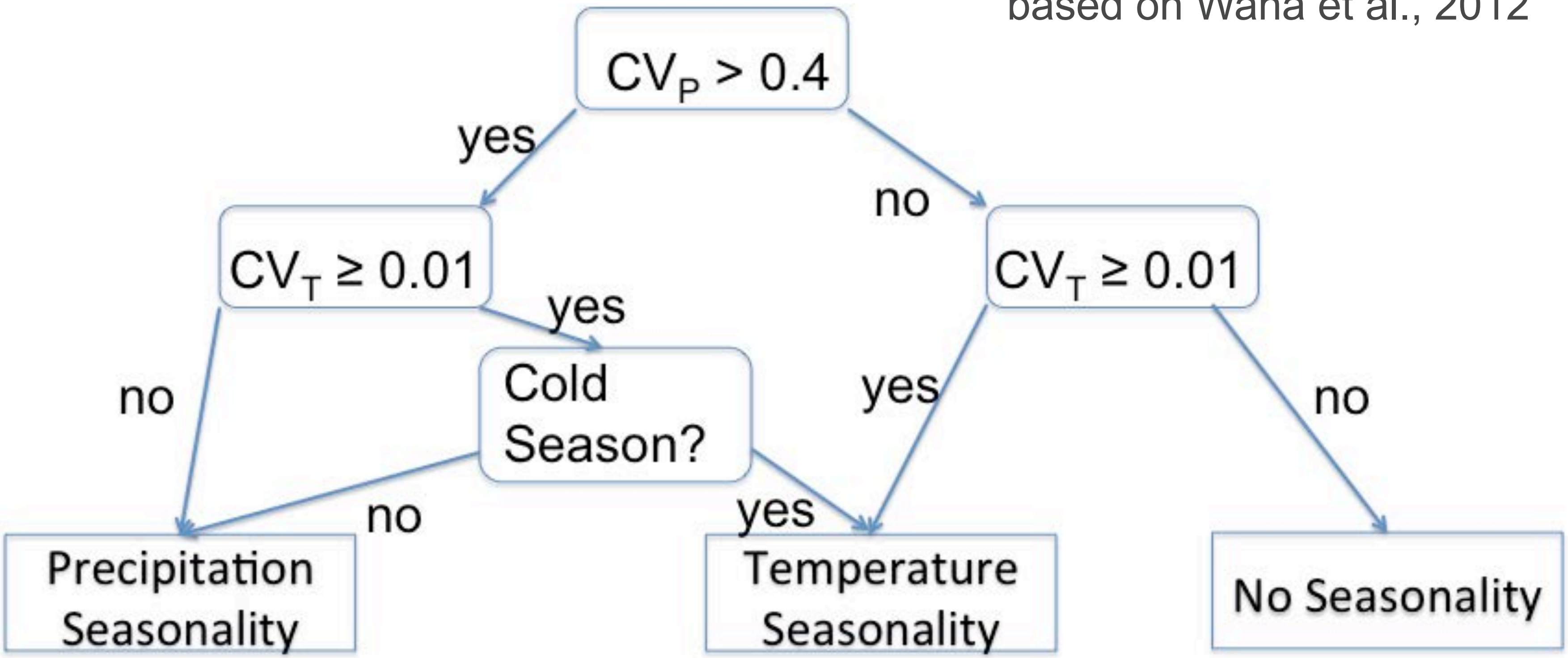
Exponential weighted moving average

Waha et al, 2012

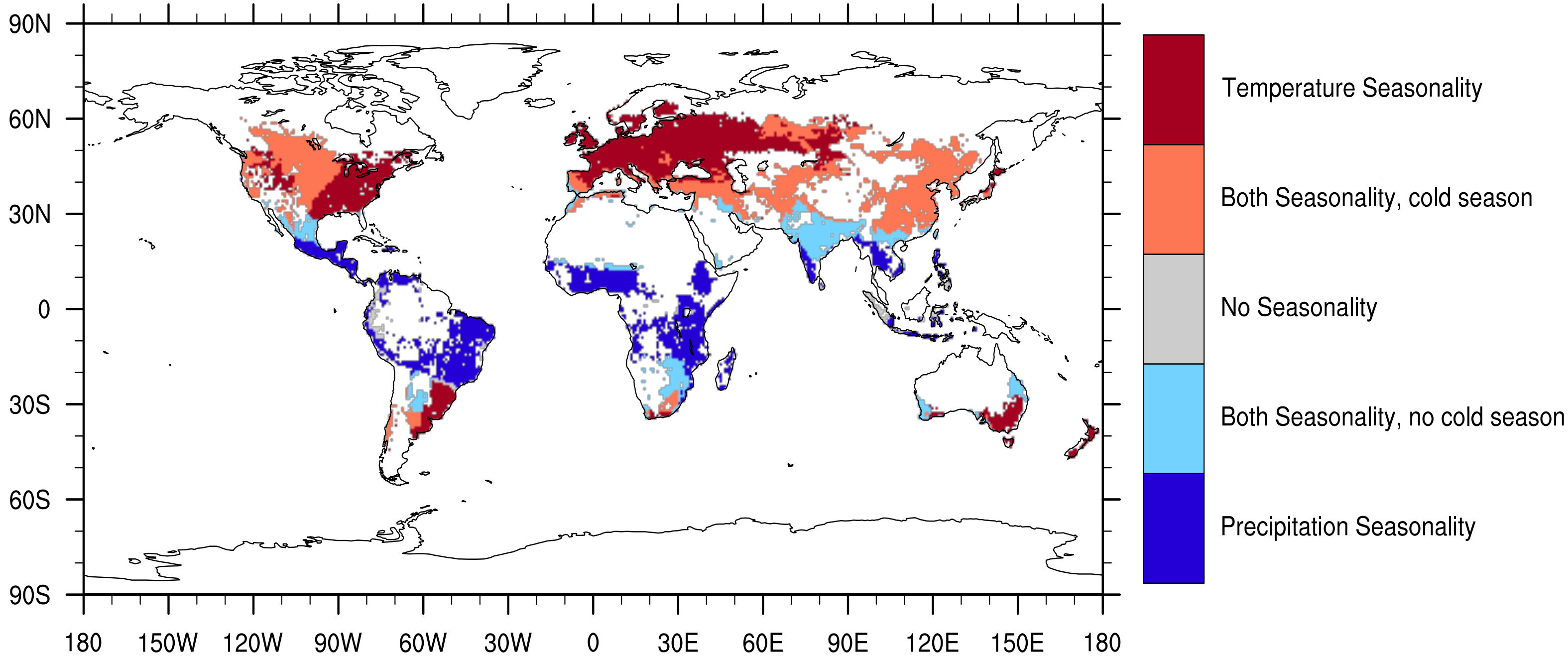
DECISION TREE FOR SEASONALITY

Based on coefficient of variance (CV) of temperature and precipitation

based on Waha et al., 2012



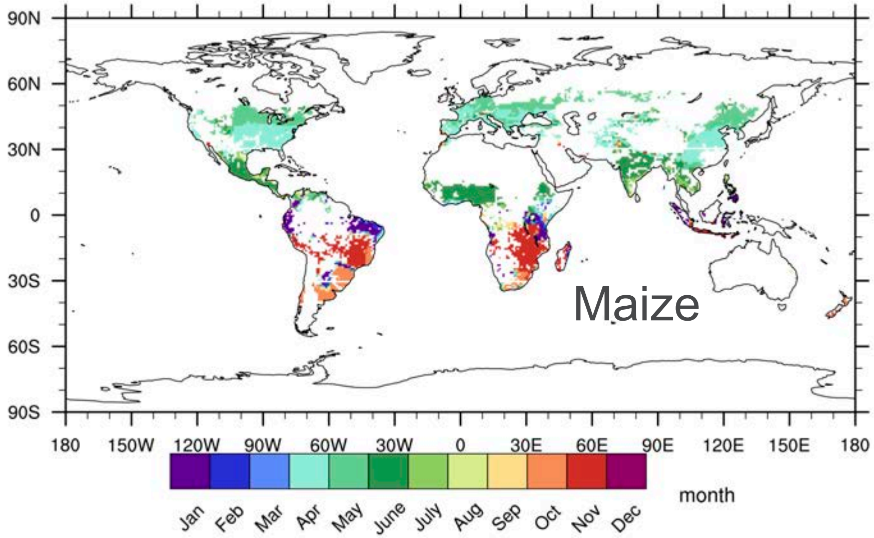
MAP OF SEASONALITY FOR PLANTING DATE DETERMINATION

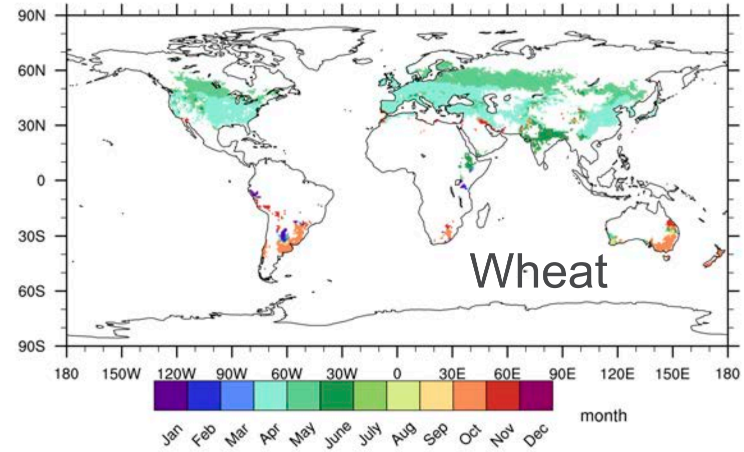


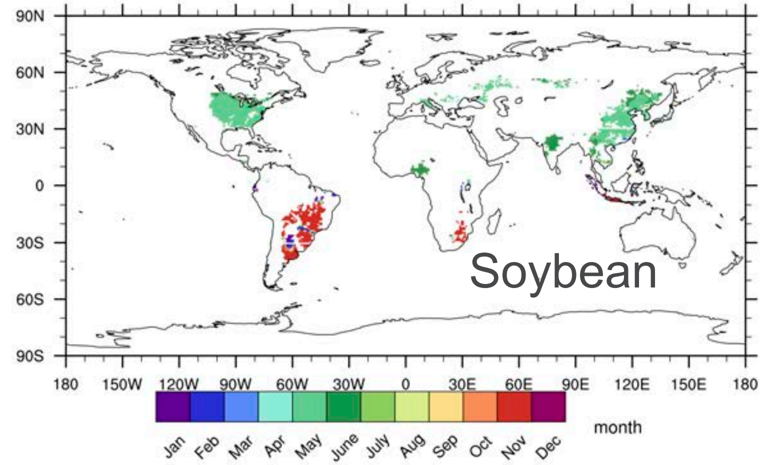
RULES AND PARAMETERS THAT DETERMINE THE MONTH AND DAY OF PLANTING

	Temperature Seasonality (red shade):		Precipitation Seasonality (blue shade):	
Crop	Plant Month: 10-day average temp. (°C)	Plant Day: 10-day average temp. (°C)	Plant Month	Plant Day
Corn	10	10	Start of largest 4-month sum of P:PET	1st day in plant month with precip. > 0.1 mm
Spring Wheat	7	7		
Soybean	13	13		

ESTIMATED PLANT MONTH USING NEW PLANTING DATE CALCULATOR

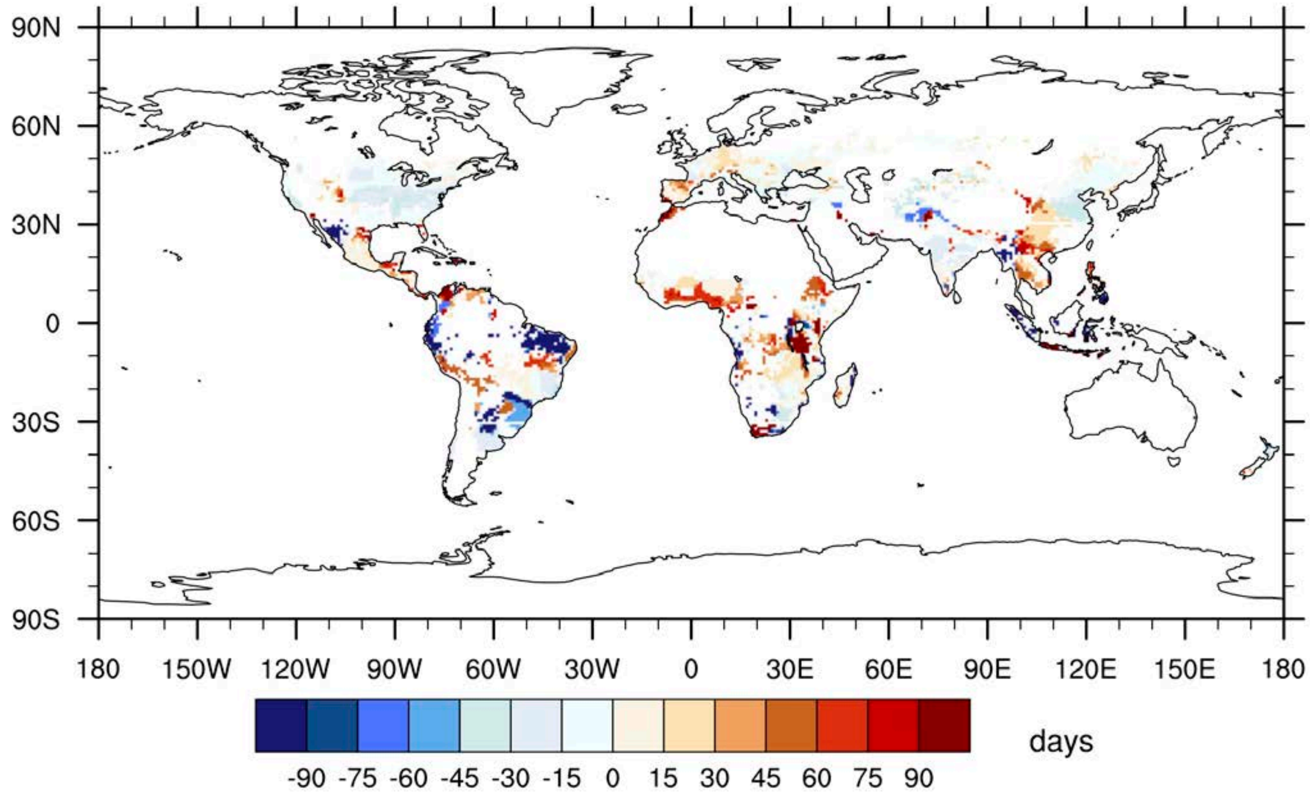






COMPARISON WITH OBSERVED PLANTING DATE (MAIZE)

Comparison is ELM – CCD (Sacks et al., 2010)



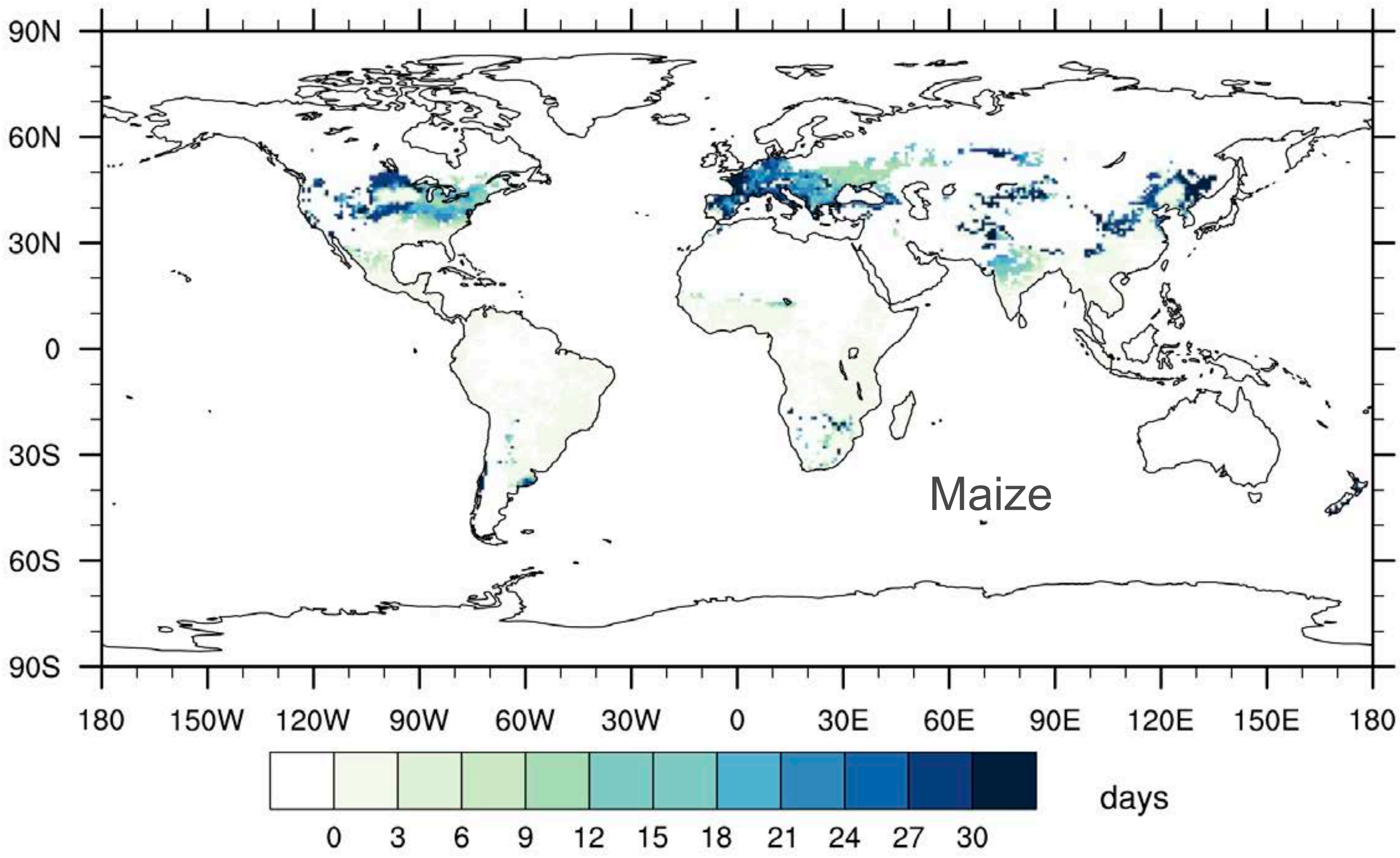
SENSITIVITY STUDY

Adjust temperatures and add soil water fraction range

	Temperature Seasonality:		Precipitation Seasonality:	
Crop	Plant Month: average temp. (°C)	Plant Day: 10-day average temp. (°C)	Plant Month	Plant Day
Corn	15	15	Start of largest 4-month sum of P:PET	1st day with precip. > 0.1 mm and 0.2 < SWF < 0.8
Spring Wheat	10	10		
Soybean	15	15		

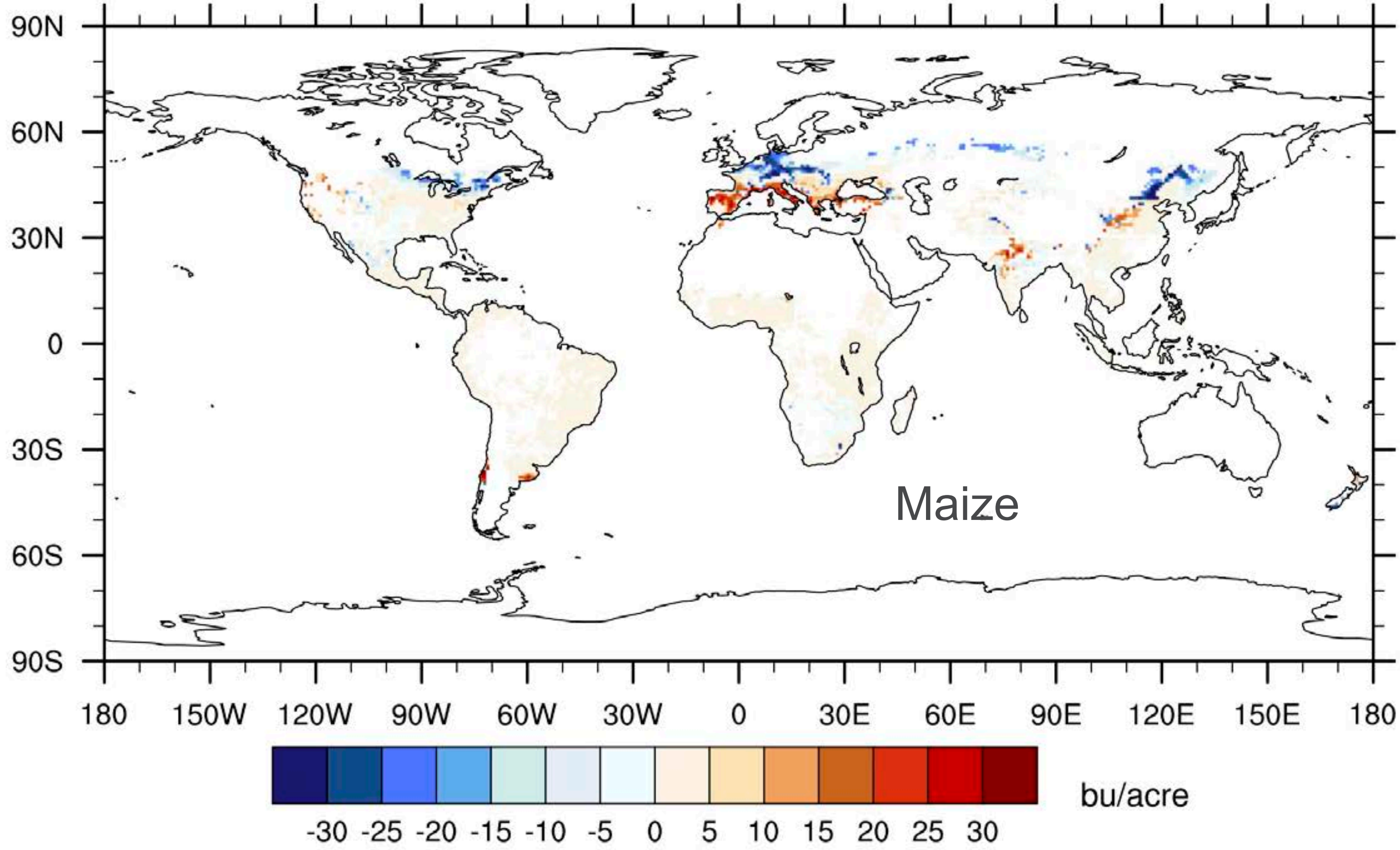
CHANGE IN PLANTING DATE USING MODIFIED PARAMETERS

Comparison is ELM Sensitivity - Control



CHANGE IN YIELD USING MODIFIED PARAMETERS

Comparison is ELM Sensitivity - Control



NEXT STEPS

- Integrate into ELM for v2
  – Need to wait for the V2 architecture updates for atmospheric forcing variables
  – Also want to move around some of the variables (increase efficiency and improve robustness)
- Explore some yield fluctuations (that may not be related to planting date)
- Work on manuscript

FUTURE WORK

TO V2 AND BEYOND

- Surface datasets for dynamic landuse
  - Testing data
  - Real LULCC
- Add new crop types (and calibrate)
  - Bioenergy crop: miscanthus or switchgrass
- Bug fixes in crop model
  - Yield variability is high
  - Soybean yield is low
- Work with Dan and Khachik on UQ and parameter calibration

THANK YOU.

QUESTIONS?